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CONTENTS

On the Morphogenesis of the Juvenile ..... *Peace Kaplan*

Bryophyte Life Forms on Slopes of Contrasting Exposures in Central New Jersey ..... *Ernest Hamm*

The Duration of the Stages of Flower Morphogenesis in Chrysanthemum. *Hamilton Parker Riley and Oliver C. Pro*

Lecanidiella, a Moss Genus New to North America ..... *Elva Jam*

Cytologic Evidence for the Occurrence of Cellular Fusion in Bacillus ..... *Edward*

The Sporangial Phase of the Downy Mildew on Eleusine Coracana with a Discussion of the Identity of Sclerospora macrospora. *M. J. Thirumalachar, Charles Gardner Shaw, & M.*

On the Morphology and Reproduction of Characium ..... *Robert C. Bak*

On the Occurrence of Gymnodinium in the Atlantic ..... *Jo*

Taxonomic Notes on the Fungi of Formosa ..... *Hsi-Ling*

A Contribution on the Fungi of Greece ..... *P.*

Fifteen New Algae .....

Torreya

Relationship in the Genus Salix as Determined by the Precipitin Reaction. ... Notes ... South-Centrally Fo... Sherry. Notes. .....

Index to American Botanical Literature .....

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 80, NO. 4, PP. 247–263 JULY, 1953

ON THE MORPHOGENETICS OF THE DESMIDS

PAAVO KALLIO

While phanerogam taxonomy has attained its newest achievements in the field of cytotaxonomy, the taxonomy of several cryptogam groups is still based more on the older system, in which the main morphological features form the only basis of the classification. Such is the case with the desmids. There are three fundamental difficulties attached to the elucidation of their cytotaxonomy. The required genetical studies are rendered difficult by the almost total lack of sexual reproduction even in genera such as *Micrasterias* and *Pleurotaenium*, which in view of their morphology and size could be expected to be favourable objects of study. The formation of zygotes in these genera is an unusual occurrence in nature and no reports of their formation in synthetic cultures in laboratories have been published. The study of chromosomes is difficult owing to the high chromosome numbers—among the largest numbers known being that of the haploid *Micrasterias rotata* (about 200)—and the small size of the chromosomes (Waris 1950a). For the above reasons the elucidation of meiosis, which is of primary importance in cytogenetic studies, encounters almost unsurmountable difficulties. A third difficulty is connected with the culture of the algae. A cytotaxonomic investigation of the desmids necessarily requires a laboratory for their culture. As emphasized already by Borge (1896), such cultures are necessary in order that it may be possible to differentiate between pheno- and genovariations, and furthermore, the study of different stages of division also requires laboratory cultures, since in nature cell division in these algae occurs only during the night.

Czurda (1937) mentions the chromosome numbers of only seven species of this group, and these numbers are only rough approximations. Waris (1950a) has counted the chromosome numbers of three more species and has in addition described in detail the division process of the cell of *Micrasterias*, which knowledge is necessary for a closer study of the species. The author has estimated the chromosome numbers of the diploid form of *M. Thomasiana* var. *notata* and has described certain details of the division process of *Pleurotaenium* (Kallio 1951).

Since in a study of the desmids it is possible to combine field observations with laboratory observations, an attempt will be made here to show in what way the laboratory may be of assistance in the elucidation of taxonomic problems in this group.

Morphological characteristics in the genus Micrasterias. Since the structure and form of desmid cells, more than physiological differences, are

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the characteristics on which their taxonomy is primarily based, the main features of their structure as they are found in the more highly developed forms will be reviewed here. For the description it is appropriate to view the cells from three directions. In the case of disciform cells, such as those of *Micrasterias* and *Euastrum*, one may consider the front view, the side view and the end view. As seen from the front, a sinus divides the cell bipolarly (Waris 1950b) into two symmetrical semicells. Perpendicular to this plane of symmetry another plane divides the cell along its length bilaterally into two symmetrical halves. When viewed from the side, the cell may be bisected by two planes of symmetry, one of which is the same as the plane separating the semicells. When viewed from the end, typical cells of *Micrasterias* have two planes of symmetry. Such forms are known as biradiate forms, but in other desmids such as *Staurastrum* and also in some forms of *Micrasterias* the number of planes of symmetry may be higher. In some species there may be only one plane of symmetry (see below).

Teiling (1950) has discussed the phenomenon which he termed radiation. A semicell which has a circular cross-section when viewed from one end is termed omniradiate in contrast to the anguloradiate forms. It is convenient to consider the latter as two groups, the biradiate and pluriradiate forms. Pluriradiate forms are known that have three, four, five or up to about twelve rays. These are called triradiate, quadriradiate, quinqueradiate, and so on (Teiling 1950). The degree of bipolar symmetry or the similarity of the semicells is determined by the limits of total variation of the semicells. In culture experiments it is possible to distinguish phenovariation from genovariation. Under all conditions of culture, as long as these conditions are kept constant, there is observed only a relatively limited variation. The age of the culture usually strongly affects the forms of the cells. The variation is smaller, the less the conditions deviate from the optimal conditions for the alga in question. The determination of the latter conditions is of prime importance in the culturing of algae (Czurda 1935), although this may require a study of the nutritional physiology over long periods (Warén 1926).

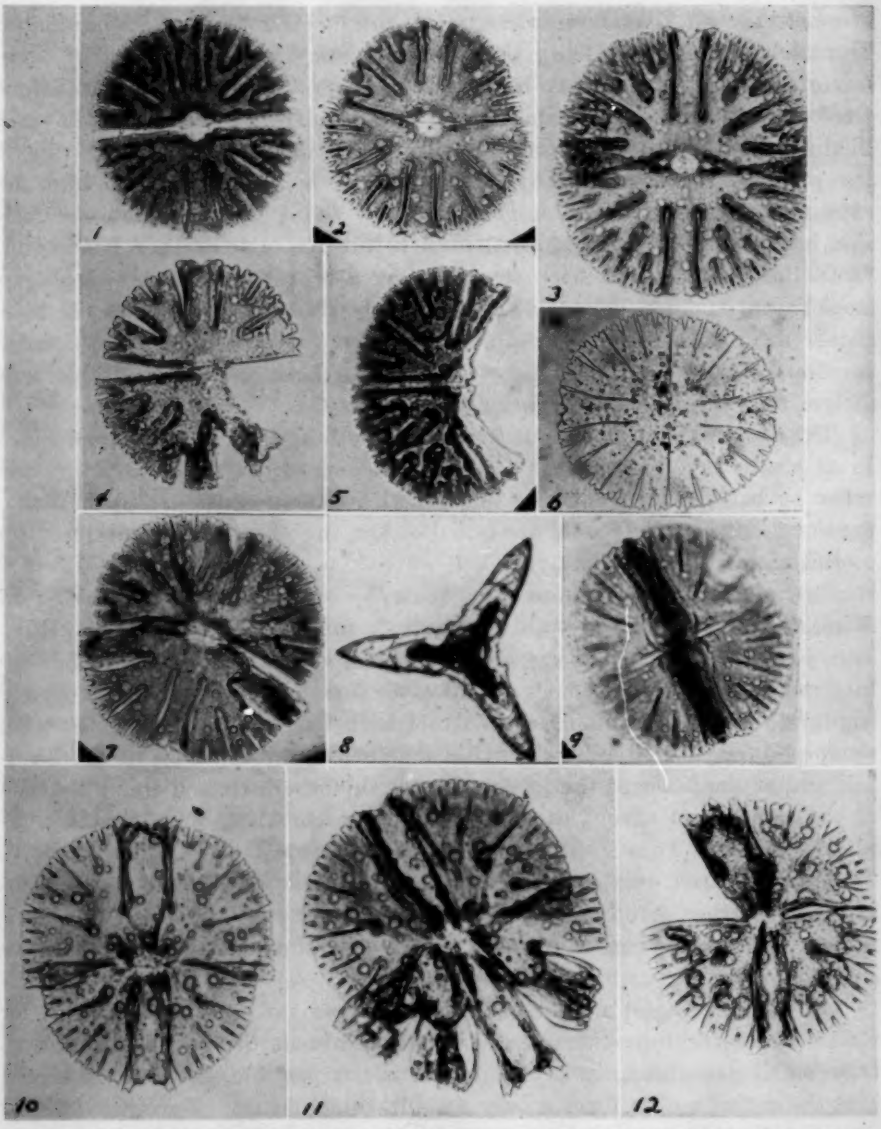
If the optimal culture conditions have not been found, it is not possible to obtain the form prevalent in nature. The form can be abnormal also when the rate of division is very high, which high rate of division may with certain limitations be considered as an indication of the suitability of the conditions. When the conditions undergo marked variations, numerous cell types may be produced in which the semicells differ greatly from each other (figs. 7, 11). Thus in *Micrasterias*, not only the size, but also the relative widths of the lobes, the width of the sinus and the form and number of teeth, undergo change. The existence of immature forms of various types indicates unfavourable conditions. In studies conducted with species of

Micrasterias (*M. Thomasiana* Arch., *M. rotata* (Grev.) Ralfs, *M. angulosa* Hantzsch., *M. radiata* Hass., *M. crux melitensis* (Ehrenb.) Hass., *M. denticulata* Bréb., *M. fimbriata* Ralfs var. *caudata* Cedergren, *M. papillifera* Bréb. and *M. truncata* (Corda) Bréb.) no difficulties have been encountered in the interpretation of the morphological characteristics which are due to the phenomenon described by Thunmark (1948). According to him the rate of division may be so high that the new semicell produced in one division has not yet attained its final form before the next division has begun. In the larger species of *Micrasterias* referred to, the interval between divisions in optimal conditions is approximately six times as long as the time required for the complete development of a new semicell, while in the smaller species the ratio is only slightly smaller. Furthermore, unfavourable conditions tend to increase this ratio.

The most interesting objects for study are those cell types (*Micrasterias*) in which the two semicells are believed to belong to two different taxonomic units (a belief which is to be taken with extreme caution). Such dichotypical (Teiling 1950) cells are based either on habitat modification or on mutation.

The author has found numerous examples of this type in his studies on *Micrasterias Thomasiana* Arch. In a culture found in nature (Turku, Ruissalo; Finland) that had been kept growing for several months in the laboratory there were numerous cells in which the form of one semicell was clearly similar to that of *M. Thomasiana* Arch. with its large protuberances with sharp-pointed small teeth projecting outwards near the base of the semicell and at the bases of the lobes, whereas the other semicell was otherwise of the same form except that such surface decorations were almost completely lacking. This latter semicell resembled most closely the form *M. Thomasiana* Arch. var. *notata* (Nordst.) Grönblad. When such a dichotypical cell is transferred to a culture tube—it grows vigorously in a synthetic culture medium—a clone is always produced that possesses the simpler form.

On the other hand a clone of *M. Thomasiana* var. *notata* (identified by Grönblad) with no protuberances when found in nature has been found to form small protuberances in culture. It is not possible, however, to assert that the actual *notata* form is only a habitat modification, since it evidently does not form large protuberances under any conditions. A further examination proves that the real *M. Thomasiana notata* and the undecorated modification of *M. Thomasiana* Arch. can be differentiated by other characteristics, as the author has shown (1951). It is remarkable that the diploid forms of these two taxonomic units, which are morphologically very similar, differ as much as they do: the diploid *M. Thomasiana* var. *notata* is a large biradiate cell with overlapping semicells (fig. 3) but the diploid "pseudo-



FIGS. 1–5. *Micrasterias Thomasiana* Arch. var. *notata* (Nordst.) Grönblad. Magnification × 140. FIG. 1. Normal haploid cell. FIG. 2. Dichotypical diploid cell with one semicell "haploid" and the other "diploid." FIG. 3. Diploid cell. FIG. 4. Dichotypical cell with one normal biradiate and one defective (uniradiate semicell). FIG. 5. Uniradiate cell.

FIGS. 6–9. *M. Thomasiana* Arch. Magnification × 140. FIG. 6. Normal haploid cell. FIG. 7. Diploid biradiate cell. In the lower semicell the lower side lobes have doubled ends. FIG. 8. Diploid triradiate cell seen from one end. FIG. 9. Diploid triradiate cell seen from the front.

notata'' is in general triradiate (triquetrous, figs. 8, 9). It is very probable that the dichotypical type described above may be found also in nature where the conditions vary, for example, owing to a drying up of the habitat. These dichotypical forms indicate the extent of phenovariation in the species, and evidently most of the other dichotypical forms found in nature and in laboratory cultures are of this nature. The production of these forms is based on the fact that the semicells are very sensitive to environmental influences when they begin to develop after division.

Biradiate diploid cells. Dichotypical cell forms in which the semicells differ genotypically[1] can arise only through somatic mutations. Of such somatic mutations based on a change in the genome (in the restricted sense of the word) the only one known at present is that caused by a change in chromosome number (Kallio 1951).

Although cytogenetical analysis is generally difficult in *Micrasterias*, the production of diploid forms from these haploid algae is easily effected. Two of the most important means by which the diploid forms can be produced are centrifugation and cold shock (Kallio 1949 and 1951). The latter probably is of importance also in nature from the evolutionary point of view.

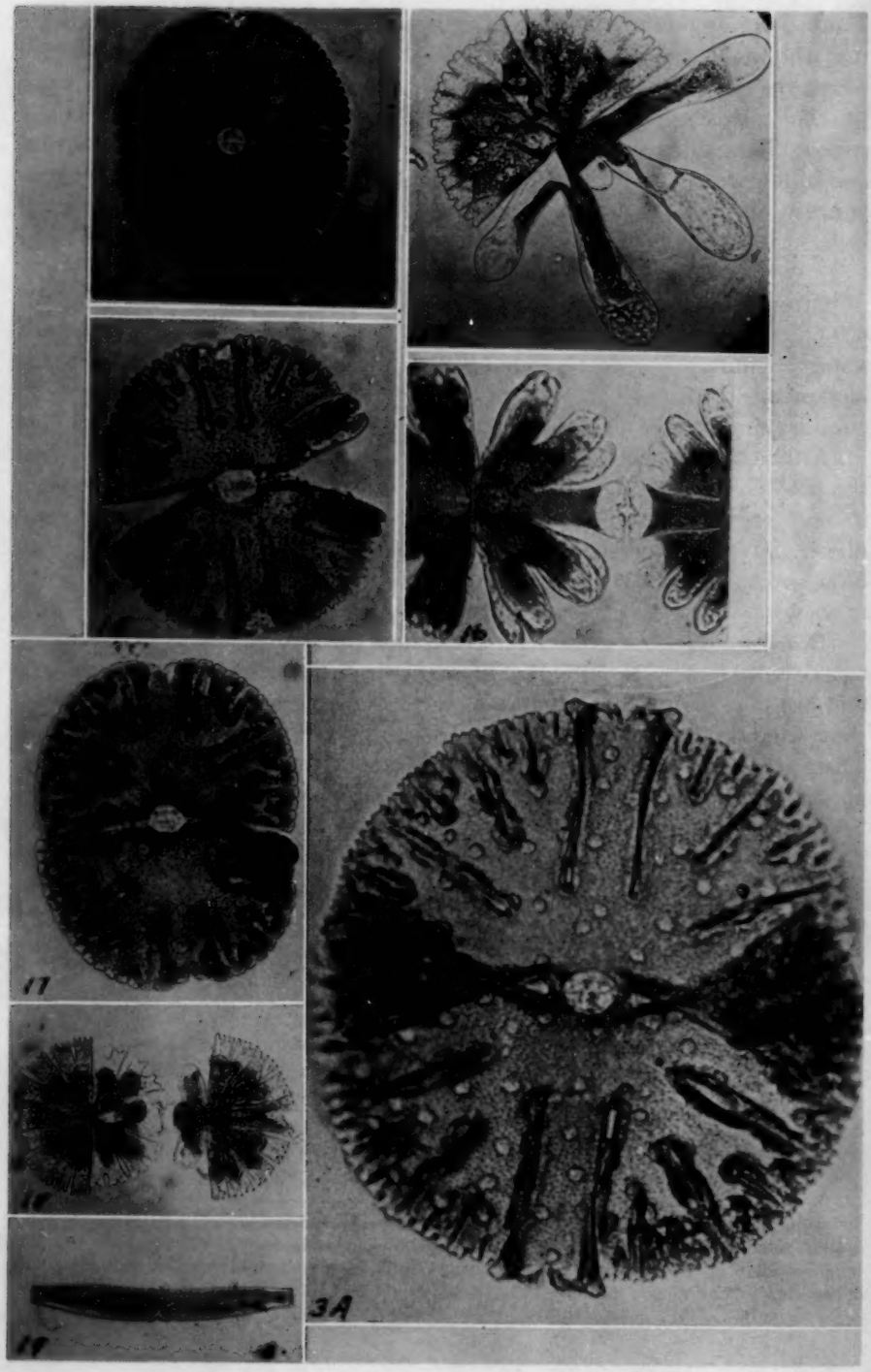
Enucleate and binucleate cells were first produced from normal cells by centrifugation (Kallio 1951). Although the former live for only one day and are to a large degree abnormal in form, being bipolarly asymmetrical, their bilateral symmetry is generally preserved (fig. 14). Also the binucleate form as well as the diploid form formed from the latter by a fusion of the nuclei are both symmetrical. The volume of the diploid form *M. Thomasiana* var. *notata* (Nordst.) Grönbl. is 2.3 times that of the haploid. The lobes are relatively wider in this form than in the haploid and the planes in which the semicells lie have a common longitudinal axis but form an angle of about 30° with each other.

The diploid cell is proportionately wider than the haploid cell. The index, the ratio of width to length, of the haploid cell is 0.92 and that of the diploid cell 0.96. Analogous changes occur as a result of diploidisation in *M. rotata*, *M. rotata* var. *evoluta* (fig. 11), *M. angulosa* (fig. 17), *M. denticulata* (fig. 15) and *M. papillifera*.

It is to be noted that the diploid *Micrasterias* is much more sensitive to

[1] This means that the semicells have been formed under the influence of different nuclei.

FIGS. 10–12. *M. rotata* Ralfs. var. *evoluta*. Magnification × 140. FIG. 10. Dichotypical diploid cell with one semicell ''haploid'' and the other ''diploid'' (cf. fig. 2). FIG. 11. Diploid cell. The upper semicell is a normal diploid semicell, in the other semicell both upper side lobes are double. FIG. 12. Dichotypical cell like the one shown in fig. 4.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changes in external conditions than the haploid form. For example, the diploid form of *M. denticulata* pictured in figure 15 very readily changes to the form pictured in figure 16. In the latter the lower side lobes are deformed in a characteristic way. They are narrower than normal and doubled. It is interesting to note that this phenomenon, the doubling of the lobes, is typical of all the eight diploid *Micrasterias* forms studied. The phenomenon is a result of unfavourable external conditions but varies with fairly wide limits. It is not observed in optimal conditions whereas under other conditions all the side lobes may be doubled, but usually the lobe doubling is observed only in one of the lobes. In the latter instance the lower side lobe has become double in *M. denticulata* and *M. Thomasiana* (figs. 7, 15). On the contrary in *M. Thomasiana* var. *notata* and *M. rotata* the doubled lobe is the upper side lobe.

Changes in radiation and the theory of plasma structure. The uniradiate cell. A disturbance of the bilateral symmetry is naturally a much rarer occurrence than a disturbance of bipolar symmetry. The "left" and "right halves" of the semicells are formed simultaneously and the subsequent external conditions affect the form and size of both in the same direction. As a result, the bilateral symmetry is often strikingly near perfection and extends to each tooth. But even bilateral asymmetry can be hereditary. From the same *Micrasterias Thomasiana* var. *notata* clone from which the previously described diploid forms were produced a bilaterally asymmetricall cell was produced both spontaneously (Waris 1950) and on cold treatment (Kallio 1951). This uniradiate cell form (fig. 5) has been described as a plasmatic mutation (Waris 1950). The cell lacks the two upper and the two lower side lobes on the same side of the longitudinal plane of symmetry and as seen from one end it has only one plane of symmetry. This cell form and the diploid form of the same strain of *M. Thomasiana* var. *notata* have analogous features. Thus the lobes in the uniradiate cell are wider than in the normal haploid cell. The cell is longer than the normal haploid, the semicells often lie in different planes and the lobes have a tendency to be double. This form is to a large degree constant and has remained unchanged in cultures for as long as ten years when many hundreds of cell genera-

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FIGS. 13–16. *M. denticulata*. Magnification ×180. FIG. 13. Normal haploid cell. FIG. 14. Enucleate haploid cell. FIG. 15. Diploid cell with three doubled lobes. FIG. 16. Diploid cells with all side lobes double.

FIG. 17. *M. Angulosa*. Diploid cell. Magnification ×180.

FIG. 18. *M. papillifera*. Enucleate (right) and binucleate (left) cells. Magnification ×180.

FIG. 19. *Pleurotaenium truncatum* var. *Farquharsonii*. Magnification ×180.

FIG. 3a. *M. Thomasiana* Arch. var *notata* (Nordst.) Grönblad. Diploid cell. Magnification ×300.

tions have formed. Genotypically (in the restricted sense again) the normal original cell type and the defect mutation are identical: no change has taken place in the nucleus, the chromosome number is the same. The difference in the cell types is based on differences in the extranuclear cytoplasm. The enucleate uniradiate cell (obtained by centrifugation) differs as much from the enucleate cell of the normal biradiate *M. Thomasiana* as the nucleate forms differ from each other.

In the formation of the defect mutation a cell is produced in which one semicell is normally bilateral, biradiate in end view, and the other semicell defective and uniradiate (figs. 4, 12). The nucleus of the cell in this dichotypical, or Janus form, if one wishes to stress the difference in the radiation (Teiling 1950), is centrally situated. The semicells have not been formed simultaneously under the influence of the same nucleus, and hence it is logical to assume, a priori, that the change which is depicted in the different morphology of the new and old semicells has occurred in the genome. However, when this form with one normal semicell and the other defective divides, the defective semicell produces its like and the normal semicell a normal new semicell. These cells have identical nuclei, but the forms of the new daughter cells are determined by the forms of the parent semicells.

The main points of the plasma structure theory are outlined in the following (Waris 1950, Kallio 1951). The septum divides the Janus form in two dissimilar parts, a defective semicell and a normal semicell, which differ in their plasma characters. The form of each semicell type is based on its own cytoplasmic structure. Both the daughter semicells which begin to develop after the formation of the septum receive their plasma from respective semicells containing different plasma. This does not presuppose a flow of plasma and a transfer of preformed structure from the old to the new semicell through the isthmus opening. On the contrary, several different series of observation have led to the opinion that the rigid structure of the new semicell is formed as a continuation of the structure in the old semicell through the isthmus into the new semicell. The basic structural units are long protofibrils (Monné 1948) that have grouped together to form bundles of different classes. The protofibril bundles of the highest degree correspond to the main morphological features of the cell. In the *Micrasterias* cell the axes of cytoplasm structure (protofibril bundles) are so arranged that they extend from one end of the cell to the other through the isthmus and are symmetrically situated. It has been established that there are three main framework axes. To one of these axes—the middle one —correspond the end lobe sectors and on both sides of this there are two symmetrically situated axes corresponding to the rays of the cell. That the number of axes is limited to three is shown by the study of the defect mu-

tation. Each of these axes is the smallest structural unit that may idiotypically be lacking in the cell, or may be added to the cell. A defective strain in which only one of the side lobes is absent is not known. These three axes may be distinguished also in the young new spherical semicells (Waris 1951). The permanent structure of the cytoplasm, which has been studied by many investigators, evidently adjoins the outer surface of the cytoplasm (Monné 1948, Waris 1950, Teiling 1950, Kallio 1951).

In the course of each cell division the long, continuous cytoplasmatic axes are broken into two at the isthmus. The broken ends provide new growth centres from which morphological units of the new semicells develop. These are symmetrically situated with respect to those of the old semicell. This phenomenon is a type of autocatalytic reproduction, which is the primary basis of inheritance. The theory of plasmastructural units or framework axes makes "intracellular pangenesis" possible in a restricted sense.

If, for some reason or other, one of the semicells lacks one of the three structural axes or a growth centre is destroyed or becomes defective, the daughter semicell will normally lack the corresponding homologous axis and the morphological part corresponding to it. These axes are individual units which do not arise de novo; they are either fully complete or are lacking altogether. If one of the side axes is lacking, a uniradiate defect mutation is formed. The upper and lower side lobes have a common axis when the new semicell begins to grow. This means that the upper and lower side lobes originate in the same growth centre and a branching of the axis occurs at a later stage of development of the semicell. The two side lobes form the ray and hence the number of side lobe growth centres determines the degree of radiation of the new semicell.

The uniradiate cell may spontaneously undergo remutation. It seems probable that the structural axis lacking is regenerated from the existing homologous side axis. The growth centre of the latter divides at an early stage in a plane parallel to the main plane of the cell and each of the two new growth centres formed produces a complete side axis. In these instances intermediate stages between the defect form and the normal form occur as semicells which are more or less folded along their longitudinal axis.

Polyploid forms involving increase in radiation. The side axes may not only decrease, but they may also increase in number. In *Micrasterias Thomasiana* Arch. this can be effected simply by inducing polyploidy. A triradiate form (fig. 8) has been obtained which is very stable under optimal conditions, and also a quadriradiate form which, however, is less stable. The biradiate diploid form without lobe doubling has only seldom been observed.

In the studies on *Micrasterias* it has been possible to elucidate the reactions involved when the degree of radiation is altered. It was not possible to elucidate in the case of the defect mutation the cause of the destruction of one of the structural axes. It was, however, found that under favourable conditions the uniradiate defect mutation remains constant. This is so within the limits set by the genome. The haploid form of *M. Thomasiana* var. *notata* has two structural variants, the uniradiate (defect mutation) and biradiate forms which are based on the differences in the plasma. The diploid of the same species never exists in the uniradiate form. Diploidisation of the uniradiate form always leads to an increase in radiation. In the diploid normal form of *M. Thomasiana* var. *notata* as well as in the defect mutation cell there is also observed a tendency to increase the degree of radiation (by a doubling of lobes).

The degree of radiation is thus largely determined by the genome, but, on the other hand, the plasmastructural units undergo a more or less independent division and possess a certain degree of stability. The genome determines the optimal degree of radiation and its stability. Thus, for example, the most stable haploid form of *M. Thomasiana* var. *notata* is the biradiate and not the uniradiate form; during a period of ten years in only three cases has a mutation of a biradiate form into a defective form been observed, whereas during the same time the reverse process has occurred hundreds of times. Of the diploid forms of the *M. Thomasiana* Arch. the triradiate form is more stable than the quadriradiate and the biradiate forms. The study of the cells with different degrees of radiation with or without differences in the genomes has revealed some important facts concerning the mode of the effect of the nucleus. The biological mode of thinking is inclined to explain the tendency to lobe doubling which is a characteristic of all the diploid forms as a feature based solely on the characteristics of the diploid nucleus. Actually, however, the new genic combination or the disturbed genic balance has very little to do with this phenomenon. We have found that in the haploid uniradiate cell the tendency to lobe doubling is as clearly evident as in the diploid cells. On the other hand, the four rays in the quadriradiate diploid cell of *M. Thomasiana* have never been observed to undergo a doubling of the lobe ends. We have here a phenomenon which is based on the correlation between the number of rays and the nuclear mass. The nuclear effect per ray, i.e., per side lobe cytoplasmic axis, determines the change in structure. The nuclear effect per cytoplasmic axis may increase in two ways: either the nucleus may undergo diploidisation while the number of cytoplasmic axes remains unchanged (diploid biradiate cells) or the number of cytoplasmic axes may decrease while the nucleus remains unchanged (e.g., in the uniradiate cell). The result is the same: a tendency to lobe doubling is observed. Also the

other characteristics typical of a diploid biradiate cell are observed in the uniradiate haploid cell. Furthermore, the four rays in the quadriradiate diploid cell are similar to the rays of haploid cells. The most interesting is the correlation of the three different forms of rays of the diploid *M. Thomasiana* Arch. The biradiate form is very similar to the diploid form of *M. Thomasiana* var. *notata* described above: As compared with the haploid

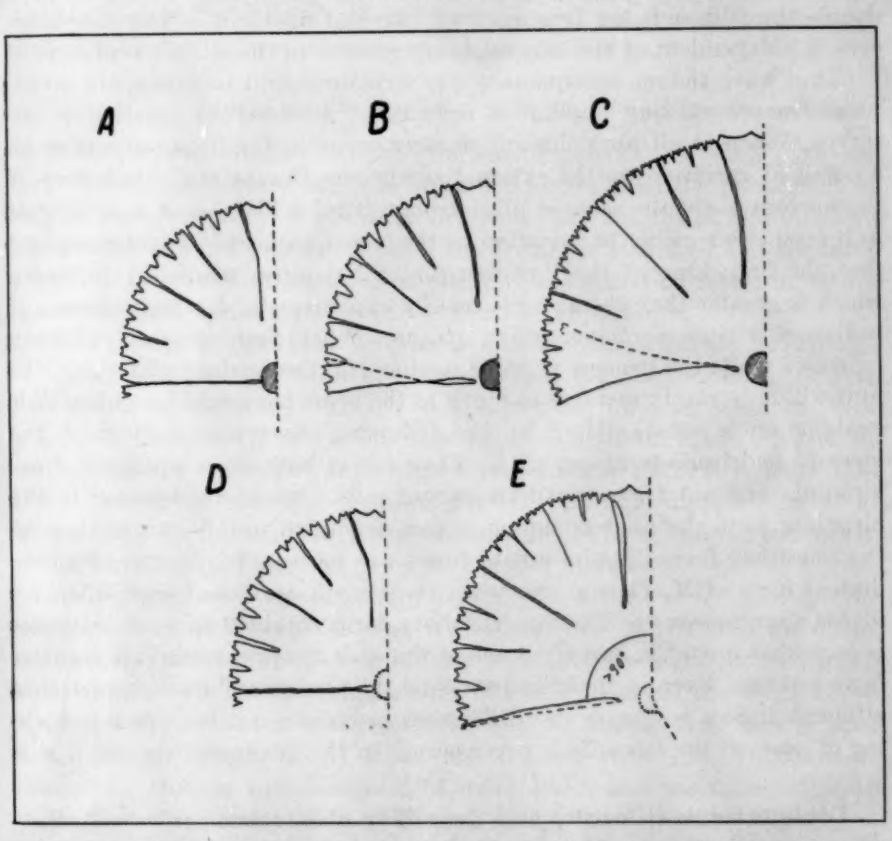

FIG. 20. Schematic drawings of different ray types in cells of *Micrasterias Thomasiana* Arch. A. Quadriradiate diploid cell. B. Triradiate diploid cell. C. Biradiate diploid cell. D. Biradiate haploid cell. E. Uniradiate haploid cell (*M. Thomasiana* var. *notata*).

the lobes are wider, the cell is relatively wider, the semicells overlap and the lobes have a tendency to be doubled. The rays of the quadriradiate form are similar to those of the haploid (biradiate) cell. The three rays of the triradiate cell are of intermediate size and form (fig. 20).

The author (1951) has suggested that the doubling of the lobe ends and the increase in the degree of radiation are related phenomena that are both

caused by an increased nuclear effect per cytoplasmic axis. The main difference between these two phenomena is the site where the branching of the cytoplasmic axis occurs. When the cytoplasmic axis branches so that the number of the growth centers in the isthmus is increased, a cell with increased radiation will be formed and this characteristic may be inherited. Lobe end doubling is not inherited. In a clone which has a tendency to double the lobe ends the frequency of lobe end doubling in the new semicells is independent of the lobe doubling present in the mother semicells.

Thus when the nuclear quantity per structural unit increases, the structural framework may undergo a branching. A threshold reaction is observed. When small physiological changes occur in the living organism as a result of variations in the external conditions, the metabolic influence of the nucleus is not the same in all divisions. Thus a division of a structural unit may occur owing to variation in the "environment." The assumption that the branching of the "growth centre" requires a nuclear influence which is greater than the average readily explains why a certain degree of radiation is more permanent than another. When the degree of radiation increases while the genome remains unchanged, the nuclear effect per lobe unit will only rarely increase as much as the branching would require. This explanation is substantiated by the following observations. Most of the known quadriradiate clones of *M. Thomasiana* have been produced from biradiate and not from triradiate parent cells, apparently because in the biradiate form the nuclear influence per structural unit is larger than in the triradiate form. Quadriradiate forms are produced from the biradiate diploid form of *M. Thomasiana* when the growth centres of both side axes divide simultaneously. The quadriradiate form obtained in such instances is somewhat unstable, and often one of the axes disappears and a triradiate form remains. Even in the triradiate type the nuclear influence is such that although it does not cause any differences in radiation it leads to a branching of some of the lobes. This never occurs in the quadriradiate cell.

Diploid forms in nature and their "key characteristics." Taxonomists in particular should pay attention to some characteristics of desmids in nature which probably imply diploidy. To determine whether diploidy is actually involved the cytological determination of chromosome number must be carried out and this is very laborious. But also the secondary characteristics such as those described above may indicate diploidy. In all the species of *Micrasterias* studied the diploid form is approximately twice as large as the haploid.[2] This applies also in all those cases in which the degree

[2] Here we naturally consider only recently formed diploid forms in which evolutionary changes have not had time to exert their effect and cause "Eigenschaftsregression" (Fagerlind 1941).

of radiation has increased. In the quadriradiate type the morphological units, the lobes or sectors, are smaller in size than in the triradiate type but the average volume is the same. This is evidently always the case unless the change in the degree of radiation is not accompanied by a genomic change. The sizes of the cells vary, but an average difference exists between haploids and diploids. Let us compare, for example, the haploid biradiate and the diploid triradiate forms. If the volume of the diploid form is twice that of the haploid form the ratio of the lengths will be

$$\text{diploid length} : \text{haploid length} = \sqrt[3]{\frac{4}{3}} = 1.10$$

when the corresponding parts have the same form. Thus when a triradiate form is found in nature which is one-tenth longer than the permanent biradiate form, diploidy is probably involved. The lengths of the biradiate and quadriradiate forms are equal if the former is a haploid and the latter a diploid. In a description of forms with unusual radiation found in nature, the actual dimensions are thus of the greatest importance.

The species of *Micrasterias* possess another characteristic by which a relatively large nuclear influence per lobe unit may be detected; the relative widths of the lobes increase with increasing nuclear influence. With respect to their morphology, this has the effect that the sinus edge of the semicell is not a straight angle, but forms an angle which is more than 180°. This is the case, for instance, for the biradiate diploid cells of all *Micrasterias* species studied. When the cell size has increased the complexity of the form, e.g., the number of teeth, has also increased.

An example of a triradiate form found in nature is *M. Murrayi* var. *triquetra* West et West (West and West 1905, plate XLV). The size of this cell is larger than that of the biradiate form and the angle at the sinus is greater than 180°. It is probable that this as well as all the other known triquetrous species of *Micrasterias* are diploids. Among these may be mentioned *M. pinnatifida* (Kg.) Ralfs var. *trigona* West and *M. Mahabuleshwarensis* Hobson var. *Wallichii* (Corda) Bréb. and the triradiate form of *M. truncata* (Grun.) West (Heimans 1942). Quadriradiate *Micrasterias* forms have not been found in nature.

Triradiate forms of another biradiate genus, *Euastrum*, have also been found in nature. Grönblad (1942 and private communication) has found such forms at Enontekiö, Finnish Lapland. It is in such arctic regions where one would expect to find abnormal forms, especially binucleate and diploid forms, similar to those produced by cold treatment in the laboratory.

The triradiate *Euastrum* cells are longer than the biradiate normal cells (table 1).

The length of the triradiate form *E. denticulatum* (Kirchn.) Gay f. *triquetra* Grönbl. mentioned by Grönblad is not known.

The dimensions given above indicate clearly that the triquetrous forms are longer than the normal forms. It must be noted that the lengths of the triquetrous forms are based on the measurement of only one to three cells and those of the normal forms on the measurement of relatively large numbers of cells. The length of the single triquetrous *E. pingue* is outside the range of the length variation of the normal form. In *E. bidentatum* one of the three cells measured is as long as the maximum value for the biradiate forms and the length of the triradiate *E. pectinatum* is about 10 per cent higher than the average length of the biradiate form. It should also be noted that the length variation in the biradiate forms is much larger than the ten per cent which represents the difference between the triradiate diploid forms and the radiate haploids. Thus the variations in length of the two types are superimposed, and a measurement of a single cell is not reliable. The measurements should be made on biradiate and triradiate forms from the same sample. Grönblad has stated (private communication) that the triradiate form is longer than the biradiate in his samples from Lapland.

TABLE 1. *The lengths in μ of three Euastrum species (Grönblad 1942) and the corresponding lengths of the normal biradiate forms (Krieger 1937).*

	Trirad. (type)	*Birad. (type)*
E. *bidentatum* Näg. f. *triquetra* Grönbl.	61–64	45–64
E. *pingue* Elfv., var. *triquetrum* Grönbl.	59	52–58
E. *pectinatum* Bréb. var. *brachylobum f. triquetra* (Kaiser) Krieger	78–80	55–84

Even on the basis of these measurements, one would be inclined to consider the triradiate *Euastrum* forms as diploids. It is difficult to confirm this cytologically since in *Euastrum* the division process is less easy to observe than, for instance, in the genera *Micrasterias, Pleurotaenium* or *Closterium*.

There is still another factor to note and this concerns the determination of the degree of ploidy on the basis of size. In dichotypical specimens the new diploid half does not equal the normal diploid semicells in size since owing to the small size of the parent semicell it is smaller than the normal diploid, although, however, larger than the haploid (Kallio 1951).

Forms differing in radiation are quite common in the genera *Staurastrum* and *Cosmarium* (Teiling 1950) and the two different degrees of radiation (dimorphism) regularly found in the different species of these genera probably do not involve genomic differences. As Teiling has mentioned, the forms with different radiation differ in the lengths of the lobes, those in the form with higher radiation being shorter. Evidently the total volume has not altered with the change in the degree of radiation (Teiling 1950, Lefèvre 1939). Turner (1922) has reported the interesting observation relat-

ing to the species *St. Dickiei* var. *parallelum* (Nordst.) that the growth of one zygote may lead to the formation of both triradiate and quadriradiate forms.

The term "facies" introduced by Teiling to differentiate forms of different radiation is ambiguous in the genetic sense. It is a purely morphological term, to which later findings based on extensive material may bring more meaning. Although evidently in some cases the dimorphism is the result of differences in genome and in other cases are purely plasmatic variations, the term may fulfill a definite requirement.

In the preceding pages only anguloradiate forms have been reviewed. The omniradiate *Pleurotaenium trabecula* (Ehrenb.) Näg. is the only omniradiate form with which the author has experimented.

If it is assumed that in the omniradiate forms, as in the anguloradiate forms, the structural axes of the cytoplasm are situated evenly over the periphery, it would be expected that in these a change in the number of axes should result in forms analogous to those found in *Micrasterias*. In the *Micrasterias* defect mutation the arrangement of the structural units is permanently asymmetric. The loss of symmetry has led to a decrease in the volume and bending of the longitudinal axis (the median lines of the end lobes form an angle at the isthmus). One would be inclined to assume that a structural defect in the omniradiate form of *Pleurotaenium* would lead to forms analogous to those of *Micrasterias*. Similar asymmetric forms have, indeed, been found among species of the genus *Pleurotaenium*. The author once encountered a form of this type in a *Pl. trabecula* (Ehrenb.) Näg. culture without understanding its value at the time when it was discovered. The cell was similar to the form of *Pl. coronatum* described by Lefèvre (1939). That the form of these cells is constant in some degree is indicated by the similar shapes of both semicells. The "teratological" phenovariations due to unfavourable conditions can hardly lead to a symmetrical deformation of the type considered here. At least one case of permanent, although slight, bilateral asymmetry, is known in the genus *Pleurotaneium: P. truncatum* var. *Farquharsonii* (Roy) West et West. In this variety, not only is a limited asymmetry observed but the cell is thinner than in the typical variety (fig. 19). It is thus probable that the changes undergone by the plasmatic structure possess evolutionary significance. Waris (1950b) has already suggested that the Genus *Closterium* may have originated in a similar plasmatic defect as the uniradiate form of *Micrasterias Thomasiana*.

SUMMARY

1. Artificially produced uni-, tri- and quadriradiate cells of some species of *Micrasterias* have been described.

2. The theory of plasmastructural units facilitates the understanding

of the morphological similarities between diploid biradiate cells and haploid uniradiate cells as well as the similar features of the rays in the biradiate haploid and quadriradiate diploid cells.

3. In all instances increased nuclear influence per cytoplasmic axis corresponding to one ray results in "diploid features": in the diploid cell because the number of the rays has remained unaltered while the nuclear mass has increased and in the uniradiate cell because the number of the rays has decreased while the nucleus has remained unaltered.

4. On the other hand one characteristic depending on the relative nuclear effect is very significant: the number of plasmastructural units (number of the rays) and the nuclear mass per cell are correlated in a high degree. The increase in the number of plasmastructural units has resulted from a branching of the existing plasmastructural units at an early stage of the formation of these units. The nucleoplasmic ratio is preserved to a large degree and thus the number and the size of the rays compensate each other.

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BRYOPHYTE LIFE FORMS ON SLOPES OF CONTRASTING EXPOSURES IN CENTRAL NEW JERSEY

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In a study of the vegetation and microclimate on north and south facing slopes of Cushetunk Mountain, New Jersey, Cantlon (1953) points out that the degree of difference in the climate between the slopes increases towards the surface of the ground. Correspondingly he states that the magnitude of difference between the layers thus appears to be the most valid indicator of microclimatic differences on slopes of contrasting exposure.

The aim of the present investigation was to obtain quantitative and qualitative data on the vegetation of the moss layers for comparison of two slopes of contrasting exposure. It was thought that a refinement of the techniques in the study of the moss layer might prove the moss layer an even better measure of microclimatic differences than the methods applied by Cantlon.

In addition to the use of cover as a quantitative measure a system of bryophytic life forms proposed by Gimingham and Robertson (1950) was adopted (fig. 1). By the use of this system it was hoped that the major features of the bryophytic community structure, resulting from the differing microclimates of the two slopes, could be depicted, or at least contrasting arrays of bryophytic growth forms might prove to be useful in comparing communities of this layer as Raunkaier's life forms (1934) are proving useful among vascular plants (Dansereau and Gille 1949, Oosting 1942, Cain 1945, Stern and Buell 1951, among others).

The study was undertaken in a small valley in the Piedmont of central New Jersey. The area is located approximately one mile east of Pluckemin, New Jersey, at geographic coordinates 40° 39′ N and 74° 38′ W. The elevation of the valley floor is approximately 400 feet above mean sea level and the 20 degree slopes face almost due north and south.

The general climate of the region approximates that for Somerville, New Jersey. The average January temperature is 30.4 degrees Fahrenheit, July averages 74.0 degrees Fahrenheit, maximum 109 degrees Fahrenheit, and the minimum is – 20 degrees Fahrenheit. The average precipitation is approximately 44 inches and is fairly evenly distributed throughout the year. The average date of the last killing frost in spring is May 2, the first in fall is October 14, and the average length of the growing season is 165 days (Reichelderfer *et al.* 1941).

The writer wishes to express his appreciation to Drs. Murray F. Buell and Edwin T. Moul for their advice and assistance throughout the investigation.

Methods. The study was made during January, February and March of 1952. In order to obtain a picture of the environment of the mosses of the two slopes the tree and shrub layers were sampled. A belt transect 10 meters wide was established in a north-south direction extending from the valley floor to a point 90 meters on each slope. The transect was subdivided into quadrats ten meters square. The individuals of each tree species

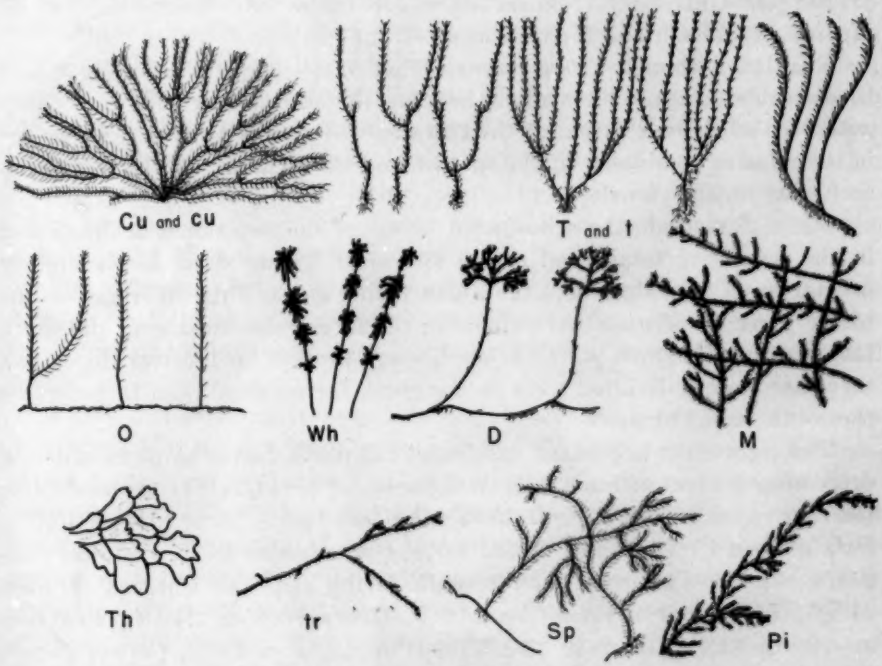

FIG. 1. Growth forms of terrestrial bryophytes: Cu and cu—Large and Small Cushions respectively; T and t—Tall and Short Turfs respectively; O—Open Turf; Wh—Whorled-Branched Forms; D—Dendroid Type; M—Compact Mat; Th—Thalloid Mat; tr—Thread-Like Forms; Sp—Spreading-Branch Wefts; Pi—Pinnate-Branch Wefts. (After Gimingham and Robertson 1950)

under one inch in diameter were counted, those over one inch were measured. The shrub layer was sampled in a belt transect 2 meters wide running the entire length of the larger transect. It was marked off in 2×10 meter segments and the number of individuals of each shrub species was recorded. The bryophytic layer was sampled in sixty-two 1×2 meter quadrats spaced two meters apart through the center of the large transect. In

each quadrat the percent cover of bryophytes, percent litter cover, depth of litter, and percent of exposed rock were estimated.

From this data density and frequency were calculated for all species in the shrubby layer, and density, frequency and basal area were calculated for each species in the arborescent layer. Cover and percent frequency were calculated for each species in the bryophyte layer.

All bryophytes were classified as to their growth form. The proposed classification of Gimingham and Robertson (1950) is followed. Specimens of all bryophytes were collected and deposited in the Chrysler Herbarium of Rutgers University. Nomenclature for the woody species is that of Muenscher (1946), and for the mosses Grout (1940).

Results. Although it is recognized that more complete sampling would be desirable general observations indicate that the data give a reasonably good idea of the vegetation of the two slopes. There is a decided difference in the relative dominance of the species, and the structure of the vegetation occurring on the two slopes.

One difference in the arborescent layers of the two slopes is illustrated in the respective total basal areas. The south facing slope has a slightly greater basal area than does the north facing slope. This difference is due to the presence of more individuals in the larger size classes on the south facing slope. However, different species are present on the two slopes and there are more individual trees on the north facing slope than there are on the south facing slope.

The eight most important species on the north facing slope in order of decreasing percent of basal area on the transect are: *Quercus prinus* 34.4%, *Quercus rubra* 18.7%, *Liriodendron tulipifera* 14.8%, *Acer rubrum* 10.2%, *Betula nigra* 4.7%, *Cornus florida* 4.6%, *Quercus alba* 4.0%, *Platanus occidentalis* 3.8%. The order on the south facing slope is: *Quercus velutina* 24.5%, *Liriodendron tulipifera* 23.9%, *Quercus rubra* 21.4%, *Fraxinus americana* 12.4%, *Quercus alba* 5.1%, *Carya glabra* 4.6%, *Cornus florida* 2.9%, *Carya cordiformis* 1.4%.

The total density of individuals (number per 900 sq. M.) in all size classes over one inch d.b.h. further illustrates the vegetational differences of the two slopes. On the north facing slope the eight most abundant species in order of decreasing total density are: *Cornus florida* 41, *Acer rubrum* 28, *Quercus prinus* 19, *Acer saccharum* 15, *Quercus rubra* 7, *Fagus grandifolia* 6, *Betula nigra* 6, *Liriodendron tulipifera* 6. The order on the south facing slope is: *Cornus florida* 21, *carpinus caroliniana* 14, *Fraxinus americana* 7, *Carya glabra* 6, *Quercus velutina* 6, *Fagus grandifolia* 5, *Betula nigra* 5, *Liriodendron tulipifera* 5.

In order of decreasing density the eight most important species occurring as seedlings and saplings on the north facing slope are: *Acer rubrum* 25.7, *Cornus florida* 23.7, *Acer saccharum* 14.4, *Fraxinus americana* 9.2, *Carpinus caroliniana* 8.6, *Fagus grandifolia* 5.1, *Betula nigra* 4.1, *Quercus prinus* 2.5. The order on the south facing slope is: *Cornus florida* 41.4, *Carpinus caroliniana* 15.6, *Sassafras albidum* 12.3, *Ostrya virginiana* 8.7, *Fagus grandifolia* 4.2, *Fraxinus americana* 3.4, *Celtis occidentalis* 3.6, *Carya cordiformis* 2.1.

Viburnum acerifolium is the most abundant shrub species but its degree of dominance is not the same on both slopes. On the north facing slope it contributes almost ninety-four percent of the total shrub density while on the south facing slope it contributes only sixty-seven percent. *Lindera benzoin* contributes twenty-six percent of the total density on the south facing slope, but on the north facing slope it contributes less than five percent. *Hamamelis virginiana* occurs on both slopes, but its contribution to the total density is insignificant. Small amounts of *Smilax rotundifolia, Ribes* and *Rubus* species are present on the south facing slope, while one individual of *Vitis* was found on the north facing slope.

The differences between the bryophytic vegetation on the two slopes are striking, and the greatest vegetational differences appear to occur in this layer. The quantitative data for this layer indicate relative differences and trends.

Eurhynchium serrulatum and *Dicranum scoparium* are the only species encountered in the quadrats on both slopes. Of these two species *Eurhynchium serrulatum* is the most important moss on the south facing slope, while on the north facing slope it ranks second in importance. However, it is fairly evenly distributed over both slopes. *Atrichum undulatum, Campylium hispidulum* and *Amblystegium varium* are present near the middle portion of the south facing slope. *Mnium affine, Pogonatum gracile, Thuidium delicatulum* and *Mnium cuspidatum* occur on the lower portion of the north facing slope. *Hypnum patientiae* and *Plagiothecium denticulatum* are near the center portion of the north facing slope, while *Dicranella heteromella* and *Leucobryum glaucum* are present near the top of this slope (fig. 2 and table 1).

The bryophytic growth forms on the two slopes are materially different. The compact mat is the most important type of growth form on both slopes. It comprises 48 percent of the cover on the north facing slope and 84 percent of the cover on the south facing slope. The short turf is the only other type of growth form present on both slopes. The growth forms in order of decreasing percent of cover on the south facing slope are: Compact mat 84%, Short turf 16%. On the north facing slope the order is:

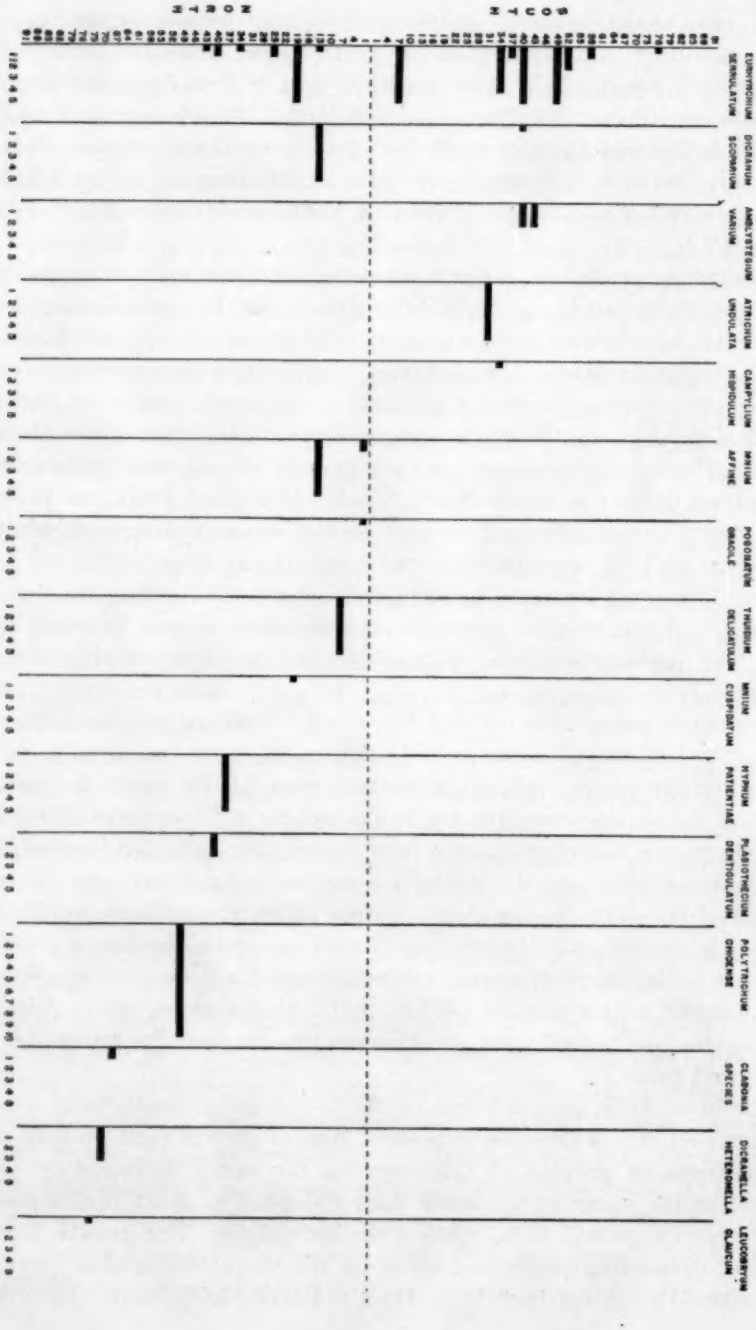
EURHYNCHIUM SERRULATUM
DICRANUM SCOPARIUM
AMBLYSTEGIUM VARIUM
ATRICHUM UNDULATA
CAMPYLIUM HISPIDULUM
MNIUM AFFINE
POGONATUM GRACILE
THUIDIUM DELICATULUM
MNIUM CUSPIDATUM
HYPNUM PATIENTIAE
PLAGIOTHECIUM DENTICULATUM
POLYTRICHUM ONDOENSE
CLADONIA SPECIES
DICRANELLA HETEROMALLA
LEUCOBRYUM GLAUCUM

TABLE 1. *Total cover, percent cover, percent frequency, and growth form of the terrestrial bryophytes occurring on both slopes. The data are based upon thirty-one 1 meter square quadrats for each slope.*

	North Facing Slope				South Facing Slope			
	Total Cover	Percent Cover	F	Growth Form	Total Cover	Percent Cover	F	Growth Form
Eurhynchium serrulatum	8.5	18.5	19	M	23.5	70.1	26	M
Dicranum scoparium	5.0	10.8	3	t	0.5	1.5	3	t
Mnium affine	6.0	13.0	6	M	.....	.....	.....	.....
Pogonatum gracile	0.5	1.1	3	t	.....	.....	.....	.....
Thuidium delicatulum	5.0	10.8	3	Pi	.....	.....	.....	.....
Mnium cuspidatum	0.5	1.1	3	tr	.....	.....	.....	.....
Hypnum patientiae	5.0	10.8	3	M	.....	.....	.....	.....
Plagiothecium denticulatum	2.0	4.3	3	M	.....	.....	.....	.....
Polytrichum ohioense	10.0	21.7	3	T	.....	.....	.....	.....
Lichen species	1.0	2.2	3	.....	.....	.....	.....	.....
Dicranella heteromella	3.0	6.5	3	t	.....	.....	.....	.....
Leucobryum glaucum	0.5	1.1	3	Cu	.....	.....	.....	.....
Atrichum undulatum	.....	.....	.....	.....	5.0	14.9	3	t
Campylium hispidulum	.....	.....	.....	.....	0.5	1.5	3	M
Amblystegium varium	.....	.....	.....	.....	4.0	11.9	6	M
Total Moss Cover	47.0				33.5			
Percent of Total Cover		1.5				1.1		

Compact mat 48%, Tall turf 22%, Short turf 17%, Pinnate-Branch Weft 11%, Thread-Like Form 1%, Large Cushion 1% (table 2).

The average litter depth on the south facing slope is more than twice that of the north facing slope. The average litter cover, however, is only

TABLE 2. *Percent of Bryophyte Growth Forms on Both Slopes*

Growth Form	Symbol	North Facing Slope Percent	South Facing Slope Percent
Compact Mat	M	47.8	83.6
Short Turf	t	17.4	16.4
Tall Turf	T	21.7	.....
Pinnate-Branch Weft	Pi	10.9	.....
Thread-Like Form	tr	1.1	.....
Large Cushion	Cu	1.1	.....

slightly greater on the south facing slope. The average rock-fragment exposure on the north facing slope is more than twice that of the south facing slope, while the percentage of rotting wood on both slopes is about equal.

FIG. 2. Actual bryophyte cover on each slope. The vertical scale indicates 1 square meter segments spaced two meters apart on each slope. The horizontal scale indicates actual bryophyte cover for each species at each quadrat along the transect. For instance in the quadrat at 40 meters on the south facing slope there is an actual bryophyte cover of 7.5% of which *Eurhynchium serrulatum* contributes 5%, *Dicranum scoparium* contributes .5% and *Amblystegium varium* contributes 2%.

A slight amount of bare ground is present on the north facing slope, although none was encountered on the south facing slope.

Discussion. The data show the tree, shrub, and moss layers of the two slopes to be materially different. As Cantlon (1953) also found, this degree of difference increases towards the surface on both slopes.

The microclimates of the two slopes appear to exert an influence on the vegetation, although stand age and history are undoubtedly of some importance in the present species distribution. The more xeric south facing slope exhibits an affinity with the oak-hickory forests of the southern Piedmont (Oosting 1942). For example, *Quercus velutina, Q. alba, Q. rubra, Fraxinus americana, Carya glabra* and *C. cordiformis* occur in greatest abundance upon this slope. On the other hand, the more mesic north facing slope shows a decided affinity with the northern-hardwood forests to the north (Nichols 1935). Here *Quercus prinus, Acer rubrum, A. saccharum, Betula nigra,* and *Platanus occidentalis* are present in high abundance and well dispersed throughout the transect.

These trends are further exemplified in the species reproduction (individuals under one inch d.b.h.) occurring on the two slopes. Those species with southern affinities are primarily restricted to the south facing slope, and reproduction on the north facing slope is mainly limited to characteristic northern-hardwood species.

The data for the shrub layers on the two slopes is comparable with that found by Cantlon (1953). The south facing slope has greater number of species, and species distribution on the two slopes is similar to that found on Cushetunk Mountain. For example, *Viburnum acerifolium* is the dominant species on both slopes, but occurs in much greater abundance on the north facing slope. In contrast, *Lindera benzoin* is present in much greater abundance on the south facing slope.

On the basis of the quadrat studies it is apparent that the bryophyte layer is better developed on the north facing slope both in terms of cover, number of species, and variety of growth forms.

It would appear that to a large extent the physical nature of the substratum affects the amount of cover contributed by the bryophyte layer. For example, the litter layer on the south facing slope has a higher cover and is more than twice as thick as the corresponding layer on the north facing slope. These conditions therefore exert a greater restricting influence upon bryophytic development on the south facing slope.

Although microclimatic differences undoubtedly exert some influence upon bryophytic cover it is believed that such differences are better reflected in terms of both number of species and variety of growth forms. For instance, of the fifteen species encountered only two, *Eurhynchium ser-*

rulatum and *Dicranum scoparium*, are common to both slopes. On the other hand, ten species are restricted to the north facing slope quadrats, while only three species are exclusive to the south facing slope quadrats. The microclimatic differences are thus illustrated through the species development occurring on the two slopes.

Certain marked differences, possibly related to microclimate are apparent between the growth form spectra for the two slopes. Of the six growth forms encountered only two, the Compact Mat and the Short Turf are common to both slopes; the remaining four types are exclusive to the north facing slope. The Compact Mat, although dominant on both slopes reaches its highest development on the south facing slope. The remaining types, on the other hand, are found only on or reach greatest development on the north facing slope. It appears therefore that, to a large extent, the growth form is a function of the microclimate. It is recognized, however, that the physical conditions of the substratum also enter into the interrelationships between type of growth form and slope exposure of the habitat. The bryophytic habitats were found to be similar to those described by Gimingham and Robertson (1950).

Summary

1. The tree, shrub, and moss layers of the north and south facing slope studied are materially different.

2. The arborescent layer of the south facing slope shows an affinity with the southern oak-hickory forest, while on the north facing slope it exhibits an affinity with the northern-hardwood forest. These trends are further exemplified in individual species reproduction.

3. The shrub layers are comparable to that found by Cantlon (1953) on Cushetunk Mountain, New Jersey.

4. The north facing slope exhibits a higher cover, greater number of species, and a larger number of bryophytic growth forms. Microclimatic differences are reflected both in terms of number of species and variety of bryophytic growth forms.

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THE DURATION OF THE STAGES OF MICROSOROGENESIS IN GASTERIA

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The chromosomes of *Gasteria* are very suitable for cytological studies, as Taylor (1931) and others have pointed out, for in most individuals the haploid set consists of four very long and three short chromosomes. The size and low number of the chromosomes and the ease of cultivating the plants indicate the suitability of this genus also for studies on the effect of radiation on chromosomes. A few such studies have been made (Marshak 1935) but the possibilities of *Gasteria* have not been explored to the extent of *Tradescantia* or *Allium*.

If *Gasteria* is to be used for radiation and cytological studies it becomes desirable to be able to determine the approximate stage of microsporogenesis from the size of the bud and to know approximately the duration of the various stages. It was the intention of this study to provide that information.

The details of meiosis and of the microspore division were carefully worked out about twenty-five years ago by Taylor (1924, 1925, 1931), but he emphasized the form and structure of the chromosomes during the various phases of division and between divisions and not the duration of the important stages of this part of the life cycle. Marshak's (1935) work on the effects of radiation on Gasteria chromosomes, also, did not discuss the time intervals nor did the paper of Johnson and Peck (1937) which called attention to the unusually heavy wall of the pollen mother cell which later disappears and may serve as stored food.

Information on the duration of the stages in the development of the male gametophyte of *Tradescantia* was obtained twenty years ago by Sax and Edmonds (1933) and has since been used by a number of investigators especially in connection with radiation studies on that genus. Sax and Edmonds marked buds with India ink and made smears each day until flowering from other buds of the same size on the same plant. Their study was made on plants grown out-of-doors and they found that there was considerable variation which was caused by weather conditions. Their findings may be briefly given since the early stages of *Tradescantia* so closely parallel in duration the results obtained in this study on *Gasteria* although the later stages are considerably different.

Sax and Edmonds (1933) observed that the prophase of the first meiotic division extends over about four days. The remaining stages of meiosis occupy two days, the fifth and sixth after the beginning of first prophase.

During the seventh and eighth days the microspore grows considerably in size. The ninth and tenth days are characterized by the appearance of vacuoles which may at first extend from one side of the microspore to the other but which at later stages of the vacuolation of the microspore are found at either side of the nucleus. During the eleventh day chiefly, the microspore nucleus divides to form the tube and generative nuclei and during the twelfth day these nuclei became clearly differentiated. The tube or vegetative nucleus increases greatly in size and goes into the resting stage. According to Sax and Edmonds it apparently begins to disintegrate even before the pollen tube is formed and seems to play little part in the further development of the microgametophyte. Johnson and Peck (1937), however, have observed a definite organization in the vegetative nucleus in mature pollen grains of *Tradescantia paludosa* and in a tetraploid hybrid. They found that the ends of the chromosomes protrude from the main body of the nucleus and sometimes can be distinguished entirely across the nulceus.

Sax and Edmonds (1933) found that the generative nucleus never goes into a typical resting stage, but retains its staining reaction as it enlarges. It soon begins to elongate to form a slender sickle-shaped body. This elongation takes place during the thirteenth day. On the next day the pollen becomes mature and pollination and fertilization occur on the fifteenth day. Johnson and Peck (1937) have observed that the generative nucleus is often split nearly its full length and suggest that separate chromosomes lie more or less parallel to one another in the generative nucleus in mature pollen.

Materials and methods. Three plants were used for this study and were identified as *Gasteria nitida*, *G. margaritifera*, and *G. Zeyheri*. The first and third had been received in 1937 from the National Botanic Gardens in Kirstenbosch, Newlands, Cape Province, South Africa while the specimen identified as *G. margaritifera* was obtained in 1938 from the Huntington Botanic Gardens in California. All three had been grown in the greenhouse of the Department of Botany of the University of Kentucky ever since. The identification of species in *Gasteria* is difficult and uncertain, so the names must be accepted with a certain amount of reservation, but they are probably as authentic as specific names can be for that genus. These particular plants were selected largely because they were in bloom at the time when it was most convenient to do the work. The various species of *Gasteria* seem to bloom under Kentucky greenhouse conditions at different times so that usually there are some plants in bloom at almost all times. These three species were studied during the spring of 1951.

In considering the various stages of microsporogenesis to be recorded, it was found convenient to adopt the same categories that Sax and Edmonds (1933) used for *Tradescantia*. Accordingly, the whole process was

divided up into the prophase of the first meiotic division, all the remaining stages of meiosis, the growth of the microspore following meiosis, the subsequent phases of the growth of the microspore characterized by its vacuolation, the division of the microspore, the differentiation of the tube and generative nuclei, the elongation of the generative nucleus, and finally the mature pollen. The time of pollination and fertilization were not observed.

The measurements which were recorded were the length of the bud and the length of the bud and pedicel. Measurements were made to 0.5 mm. After the bud was measured it was removed from the plant and brought into the laboratory where its stage of microsporogenesis was determined by the acetocarmine smear technic after fixation in one part glacial acetic acid and three parts ethanol. The mean lengths were determined for the buds in the various stages of development and these means are listed with the standard errors in tables 1, 2, and 3. The ranges are also given.

TABLE 1. *The size of buds (in mm.) of Gasteria nitida in which various stages of microsporogenesis are found and the approximate days after the beginning of meiosis in which these stages occur.*

Stage of Development	No. buds	Length of bud		Length of bud and pedicel		Days after beginning of first prophase
		Mean	Range	Mean	Range	
PMC	21	4.28 ± 0.12	3.0– 5.0	4.92 ± 0.11	3.5– 5.5	1–4
Meiosis	13	4.60 ± 0.15	4.0– 5.5	5.62 ± 0.11	5.2– 6.5	5–6
Growth of microspore	24	5.97 ± 0.13	5.0– 7.0	7.40 ± 0.13	5.5– 8.5	7–8
Vacuolation of microspore	33	7.53 ± 0.56	6.0–10.5	10.23 ± 0.30	8.0–15.5	9–11
Microspore division	19	10.24 ± 0.26	8.5–12.0	14.61 ± 0.41	11.0–17.0	12–13
Differentiation of nuclei	25	12.26 ± 0.16	11.0–13.5	17.32 ± 0.25	15.0–19.0	14–15
Elongation of generative nucleus	21	16.40 ± 0.32	14.0–18.0	22.45 ± 0.38	19.0–25.0	16–20
Mature pollen	11	19.14 ± 0.30	17.0–20.0	25.90 ± 0.24	25.0–27.0	20–25

The method of determining the duration of the various stages was essentially that of Sax and Edmonds (1933). A bud was measured and marked with India ink and a tag, and another bud of the same size on the same plant was examined cytologically or, more frequently, an adjacent bud was so examined. The marked bud was measured every day until maturity and a bud of similar size was examined for its stage of division.

All measurements and cytological studies were made by the junior author but the senior author accepts full responsibility for any errors.

Observations. In view of Taylor's (1924, 1931) excellent descriptions of meiosis and the microspore divisions in *Gasteria*, it is unnecessary to redescribe them here, but a word might be said of the chief features of the

TABLE 2. *The size of buds (in mm.) of Gasteria margaritifera in which various stages of microsporogenesis are found and the approximate days after the beginning of meiosis in which these stages occur.*

Stage of Development	No. buds	Length of bud		Length of bud and pedicel		Days after beginning of first prophase
		Mean	Range	Mean	Range	
PMC prophase	18	4.29 ± 0.13	3.0– 5.0	4.85 ± 0.14	3.5– 6.0	1–4
Meiosis	11	5.01 ± 0.14	4.0– 6.0	5.62 ± 0.14	5.0– 6.5	5–6
Growth of microspore	11	6.52 ± 0.30	5.2– 8.5	7.70 ± 0.27	6.2– 9.5	7–8
Vacuolation of microspore	17	9.53 ± 0.25	7.5–11.5	11.38 ± 0.25	10.0–13.5	9–11
Microspore division	9	11.61 ± 0.19	10.5–12.5	14.28 ± 0.36	12.5–16.5	12–13
Differentiation of nuclei	17	14.29 ± 0.30	12.5–16.5	19.18 ± 0.41	16.5–22.0	14–16
Elongation of generative nucleus	25	18.88 ± 0.48	15.0–22.5	25.79 ± 0.62	22.0–31.5	17–19
Mature pollen	17	24.65 ± 0.33	22.0–26.5	34.76 ± 0.45	31.0–38.0	20–25

other stages of development which were considered. No attempt was made to determine the duration of the individual phases of meiosis or the size of the buds which contain them since on many slides all phases from prophase of the first division to telophase of the second may be found.

After meiosis, the young microspore has many granules in the cytoplasm. They tend to collect around the nucleus although many lie at random throughout the cytoplasm. Later, the nucleus seems to enlarge and many small vacuoles appear along with the granules. During the period termed "vacuolation of the microspore," these vacuoles become larger and more

TABLE 3. *The size of buds (in mm.) of Gasteria Zeyheri in which various stages of microsporogenesis are found and the approximate days after the beginning of meiosis in which these stages occur.*

Stage of Development	No. buds	Length of bud		Length of bud and pedicel		Days after beginning of first prophase
		Mean	Range	Mean	Range	
PMC prophase	13	3.12 ± 0.11	2.5– 3.5	3.52 ± 0.12	3.0– 4.0	1–4
Meiosis	13	3.96 ± 0.09	3.5– 4.5	4.60 ± 0.05	4.5– 5.0	5–6
Growth of microspore	18	4.84 ± 0.13	4.0– 6.0	5.90 ± 0.16	5.0– 7.5	7–8
Vacuolation of microspore	16	6.88 ± 0.14	6.0– 8.0	8.94 ± 0.12	7.0–10.0	8–9
Microspore division	15	7.27 ± 0.25	5.8– 9.0	10.63 ± 0.24	8.0–12.0	10–11
Differentiation of nuclei	27	9.83 ± 0.22	7.5–12.0	14.52 ± 0.35	11.0–17.0	11–13
Elongation of generative nucleus	25	13.64 ± 0.36	11.0–17.5	18.96 ± 0.32	17.0–22.0	14–17
Mature pollen	24	17.40 ± 0.19	15.0–19.0	23.56 ± 0.37	20.0–28.0	18–22

numerous. After the microspore division the tube and generative nuclei at first appear alike but the generative nucleus soon becomes compact and more deeply stained while the tube nucleus enlarges and is less deeply stained. These events have been characterized as the "differentiation of the nuclei." The generative nucleus then enlongates and becomes sickle-shaped while the cytoplasm seems to lose its vacuoles and to become densely granular.

Both the meiotic and the microspore divisions appeared to be approximately equally frequent at all hours of the day and night or, at least, no definite times seemed noticeably more advantageous than others for obtaining division figures. During the pollen mother cell prophase the contents of the anther were watery and translucent and the pollen mother cells were colorless or perhaps a very pale green. As meiosis progressed, the sap in the anther became less transparent and more milky. After the vacuolation of the microspore, the pollen was opaque and light yellow. At the end of the microspore division it was completely opaque and somewhat orange and when mature was deep orange.

The sizes of the buds which contain cells in the various stages of microsporogenesis are listed in tables 1, 2, and 3. It can be observed from the ranges which are given in these tables that there is considerable overlapping, for the shortest bud of one stage is frequently shorter than the largest one of the next earlier stage. However, the successive means are significantly different.

It is interesting to note that there are considerable differences in the average size of the buds of the three species at various stages. For example, both the bud and the bud plus the pedicel are of the same length at the time of the pollen mother cell prophase in *G. Zeyheri*. The similarity in the size of the buds in the first two species is soon lost, however, for buds of *G. margaritifera* are larger during meiosis and all subsequent stages. On the other hand, when both the bud and its pedicel are measured together there are no great differences between the two species during meiosis and during the later stages up to the time of the differentiation of the nuclei. Then *G. margaritifera* becomes larger and remains larger throughout the remaining stages. Both the length of the bud and that of the bud and pedicel are less in *G. Zeyheri* than in either of the other two species when the bud is first measured and during all subsequent stages.

The duration of the PMC prophase, of meiosis and of the growth of the microspore is the same in each of the three species and is similar to the results Sax and Edmonds (1933) obtained in *Tradescantia*. However, the growth and vacuolation of the microspore consume only three days in *G. Zeyheri* but extend over five days in each of the other species. Thereafter, *G. Zeyheri* is always in advance and is ready for pollination on the 23rd

day. The two other species follow almost identical patterns and are ready for pollination on the 26th day. In these two species the duration of the respective stages is almost identical even though the length of the buds is considerably different after the PMC prophase. All three species take longer than Sax and Edmonds found in *Tradescantia* during all the later stages.

From these three tables it is clear that before beginning any radiation experiment in *Gasteria* it is necessary to determine the characteristic behavior of the particular species or plant to be used rather than rely on data that are general for the whole genus.

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LORENTZIELLA, A MOSS GENUS NEW TO NORTH AMERICA

ELVA LAWTON

A group of mosses sent for identification by Dr. T. C. Frye of the University of Washington included a specimen marked "*Acaulon* or *Phascum*," collected by Dr. McAllister in Texas near Austin in June 1941 and issued by Dr. Grout under the number 421. Examination of the plants sent by Dr. Frye showed a conspicuous horizontal stem fifteen millimeters or more in length, with erect branches bearing rosettes of leaves with long awns. This outstanding characteristic and the exceedingly large spores found in the capsules seemed to rule out both *Acaulon* and *Phascum* and reference was made to Brotherus (1924). It was soon quite evident that the moss belonged to *Lorentziella* C. Müll. of the Gigaspermaceae, a genus heretofore known only from South America. After reaching this conclusion, it was learned that in 1945 Dr. Grout had named the moss *Acaulon megalosporum*, a new species, and at the same time he named another new species of the same genus, *Acaulon Runyoni* for the collector, Mr. Robert Runyon of Brownsville, Texas. It is fortunate that some observations were made before it was learned that the moss had been named, or it might have remained under the genus *Acaulon* indefinitely.

Specimens of *Lorentziella* and *Acaulon* were borrowed from a number of herbaria for study and comparison in order to determine whether the Texas plants belonged to any of the five species of *Lorentziella* from South America, or if different species are present in the northern hemisphere. Paris (1905) lists *Lorentziella Uruguensis* C. Müll., but this is obviously another name for either *L. glauca* or *L. globiceps* and was never published by Müller, and the only reference to the name was made by Bescherelle in 1877 when he refers to a manuscript by Müller. The earliest record of a moss in the group is found in Mitten's description in 1869 of *Leptangium imbricatum*, a moss collected in Uruguay in 1868 by Gilbert and this species was transferred to the genus *Lorentziella* in 1909 by Brotherus. In the description Mitten does not mention an operculum, but in his key to the genera of the Funariaceae where he placed *Leptangium*, he differentiated it from other genera by the presence of an operculum. Other species which have been described for the genus *Leptangium* had operculate capsules and have since been transferred to *Erpodium* or *Gigaspermum*. In 1879 Müller gave the first complete and adequate description of the genus and named it *Lorentziella*, but the publication of Bescherelle on *Lorentziella paraguensis* had appeared in 1877, and in it he referred to a manuscript by Müller. The published names of the five species of *Lorentziella* from South America are

as follows: *Lorentziella imbricata* (Mitt.) Broth. [as *imbricatum*]; *Lorentziella paraguensis* Besch. 1877; *Lorentziella glauca* C. Müll. 1879; *Lorentziella globiceps* C. Müll. 1879; *Lorentziella Giberti* C. Müll. 1888.

In his description of *L. paraguensis,* Bescherelle gave the number of the specimen as 1258, collected by Balansa in Paraguay, and envelopes with this number were found in the herbarium of the New York Botanical Garden and in the material loaned by the herbarium of the Museum of Natural History at Paris, and thus the type was available for study. The Mitten herbarium is at the New York Botanical Garden and a natural conclusion is, that the type of *Leptangium imbricatum* Mitt. should be there, but there are no specimens under the name, *imbricatum* in the Mitten collection. There are specimens of *Lorentziella Giberti* C. Müll. and of *Lorentziella paraguensis* Besch.; one envelope of *L. Giberti* bears the following data, "no. 714 and no. 724, Gibert, Augusto 1868, Montevideo, Uruguay." Without doubt this must be the type of Mitten's *Leptangium imbricatum,* for it is the only specimen of this group of mosses in the Mitten herbarium which was collected before he wrote his description, and apparently he changed the name from *Leptangium imbricatum* to *Lorentziella Giberti.* But Mrs. Britton and Mr. Williams reached a different conclusion judging by the notes they left on the specimens. Mr. Williams put his initials after the following note written on the envelope of *Lorentziella paraguensis* Besch. in the Mitten collection, "This is evidently *L. imbricata* of Mitten. R.S.W.;" and Mrs. Britton wrote on the genus cover, "*Lorentziella paraguensis* Besch. equals *L. imbricata* Mitt. fide R.S.W." Some one at the herbarium at Paris left notes which, to some extent, confirm the conclusion that number 714 is the type, for the envelope with the specimen bearing this number had the following written on the outside, "*Lorentziella Giberti* or *glauca* C. Müll. (*Leptangium imbricatum* Mitt.) Montevideo, no. 714," and on the card inside the envelope the following, "*Leptangium imbricatum* (*Lorentziella*) *glauca,* Montevideo, Gibert 714." In this connection it should be noted that Herter in his list of mosses of Uruguay published in 1933, gives the following; *Lorentziella Giberti* C. Müll., H. no. 1212, and *Lorentziella imbricata* (Mitt.) Broth. G. 714. Mr. Bartram's herbarium contains Herter's 1212 and he called it *Lorentziella imbricata* (Mitt.) Broth.

No herbarium specimens of *Lorentziella glauca* C. Müll. have been found and only one collection of *Lorentziella globiceps* C. Müll. has been available, the one made by Hosseus (1938) at Cordoba in Argentina, identified by Mr. Bartram and loaned by him. Herbarium material from the following individuals and institutions has been borrowed and after each specimen listed below, the herbarium where each may be found is given in abbreviated form; Dr. T. C. Frye, University of Washington, Mr. E. B. Bartram, Dr. H. S. Conard, New York Botanical Garden, U. S. National Herbarium,

Cryptogamic Herbarium of the Museum of Natural History at Paris, University of Texas, Dr. Eula Whitehouse of Southern Methodist University, and the Farlow Herbarium of Harvard University. The following collections were examined and are listed under the names given on the herbarium specimens.

Lorentziella Giberti C. Müll. Uruguay, Montevideo, Aug. 1868, Gibert 714 and 724 (N.Y.B.G., Paris); Uruguay, Montevideo, Agosto, Sept. 1873, *Arechavaleta* 244 (N.Y.B.G.); Uruguay, Montevideo, Aug. 1876, Arechavaleta 233 (N.Y.B.G.); Uruguay, Montevideo, La Paz, 1879, Gilbert 1248 (N.Y.B.G.).

Lorentziella paraguensis Besch. Paraguay, l'Assomption, 1876, Balansa 1258 (type), (N.Y.B.G., Paris); Paraguay, l'Assomption, June 1881, Balansa 3623 (N.Y.B.G., Paris, U.S.); Uruguay, Santa Lucia, F. Felippone 222 (277) (Paris).

Lorentziella imbricata (Mitt.) Broth. Uruguay, Dep. of Colonia, Estanzuela, July 1928, leg. W. G. Herter 1212 (Bartram, Farlow).

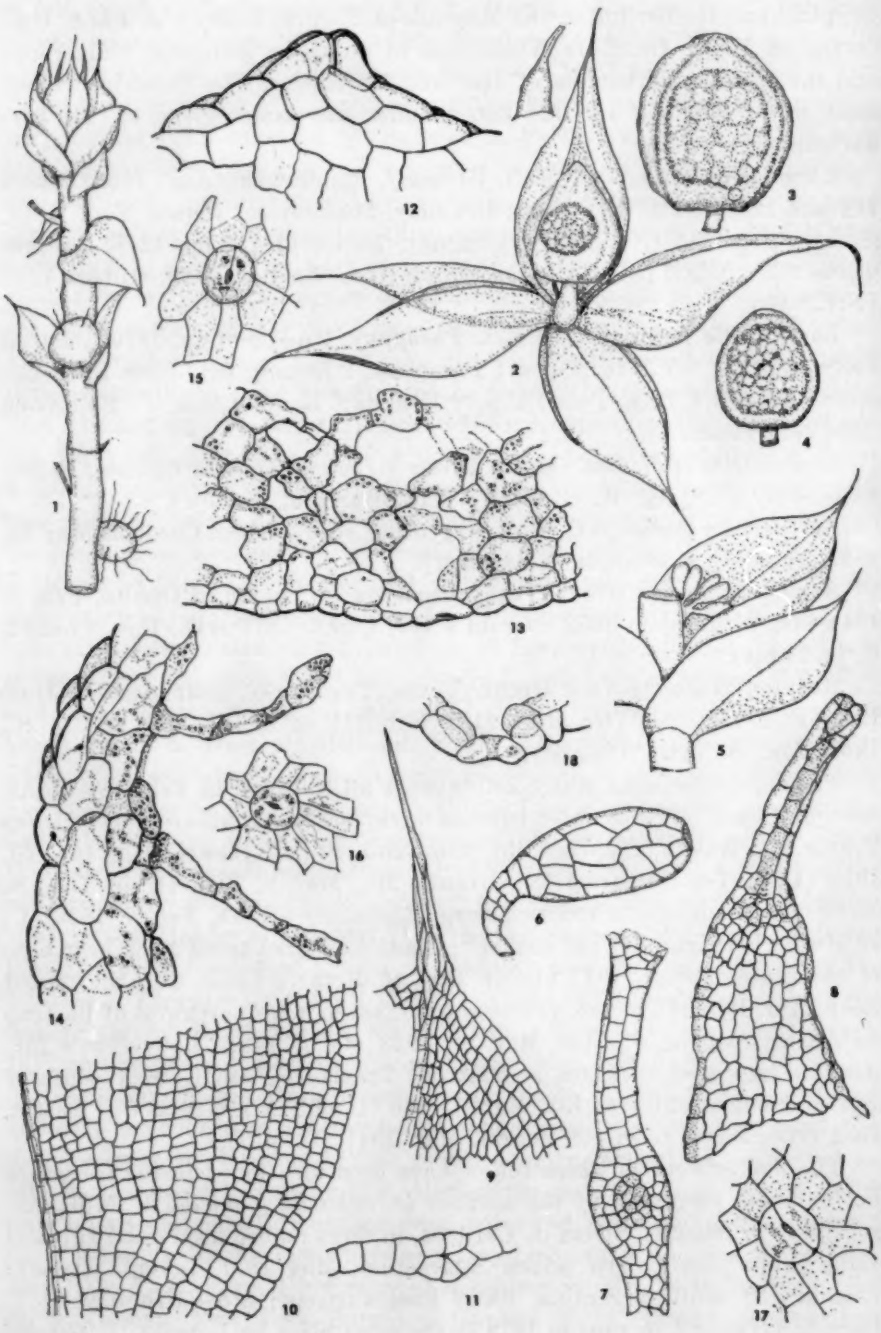
Lorentziella globiceps C. Müll. Argentina, supra urbem Cordoba, May 25, 1932, leg. C. C. Hosseus 563 (Bartram).

Acaulon Runyoni Grout. Texas, Cameron Co., north of Olmito, Feb. 2, 1944, coll. R. Runyon 3653, (Grout's 467, type), (N.Y.B.G., U.S., Conard, U. of Texas).

Acaulon megalosporum Grout. Texas, Travis Co., near Austin, June 1941, F. McAllister, (Grout's 421, type), (U. of Wash., N.Y.B.G., U.S., U. of Tex., S. Meth., Conard).

The eight specimens which follow were all collected in Texas by McAllister and were called *Acaulon rubrum* or *rufescens*, but all are *Lorentziella:* Travis Co., Austin, Cameron Rd. and 32nd. St., Liverwort Hill, Jan. 20, 1919 (U. of Tex.); Burnet Co., Granite Mt., Mar. 9, 1929 (U. of Tex., S. Meth.); Gillespie Co., Fredericksburg, Enchanter's Rock, Feb. 7, 1930 (U. of Wash., herbarium of the author); Llano Co., Enchanted Rock near base of mountain, Feb. 1, 1931 (U. of Tex., S. Meth.); Llano Co., Enchanted Rock, Mar. 1931 (U. of Tex.); Bastrop Co., seven miles northwest of Bastrop on Austin road near ponds, Mar. 22, 1933 (U. of Tex.), not Grout's 258, *Acaulon rufescens*, collected at Bastrop; Travis Co., Austin, road south of golf course near Cameron Rd., Mar. 3, 1936 (U. of Tex.); Travis Co., Austin, East Ave., across from golf course, Mar. 1941 (U. of Tex.).

The five collections which follow have been mentioned in the literature but have not been seen by the author: *Lorentziella globiceps* C. Müll. Argentina, Cordobensis, Sierra de Cordoba, in terra umbrosa sylvestri rupestri vallis prope 'der Calera' supra cataractum, May 1871, Lorentz (type); *L. glauca* C. Müll. Argentina, Entre Rios, Concepcion del Uruguay, 1877, Lorentz (type); *L. glauca* in 1878 in the same place by Lorentz; *L. Giberti*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C. Müll. Uruguay, Montevideo, La Paz, 1873, Gibert, doubtless the type as it was given by Müller in 1888 with this data; *L. Giberti* C. Müll. collected by Felippone and listed by him in 1912. Is this the *L. paraguensis* of the Paris herbarium collected by Felippone at Santa Lucia, Uruguay? In 1901 Müller discussed the four species known to him and gave data on various collections made before that time. Apparently he knew nothing about Mitten's *Leptangium imbricatum*.

Permanent slides were made of the nineteen collections studied, and the various specimens from South America were compared with each other, especially those believed to be the types, and with the specimens from Texas without accomplishing the primary aim of arriving at a definite conclusion as to what species have been found in Texas. In fact, it did not seem possible to find good characters to distinguish the South American species from one another. One feels that identification has been somewhat on a geographical basis, with two species from Argentina, one from Paraguay, one or two from Uruguay, and two from Texas. There has been one departure from this practice for a specimen collected by Felippone in Uruguay was called *L. paraguensis*, at least on the envelope in the Paris herbarium, but in 1912 Felippone gives one species, *Giberti* in his list of mosses of Uruguay.

Brotherus in 1924 gave spore size and the presence of an apiculus on the capsule as the differentiating characters for the five species which he named. In his descriptions of *Acaulon megalosporum* and *A. Runyoni* in 1945, Grout also used spore size and the apiculus of the capsule. Brotherus states that an apiculus is absent in *paraguensis* and present in the other species. But the type specimen of *L. paraguensis*, number 1258, shows an apiculus on the capsule; figure 2 is of *L. paraguensis*, number 3623, collected by Balansa, who collected the type in the same region a few years earlier. Grout states that number 421 has an apiculus but that number 467 does not have one. The capsule illustrated in figure 3 is of Grout's 421, and figure 4 is of his number 467. The apiculus seems to be quite variable and in some cases it may be apparent if the capsule is seen in side view, and

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FIG. 1. Habit of branch with vegetative leaves and enlarged bodies on the stem. ×14. FIG. 2. Capsule of Balansa's 3623 with perichaetial leaves and calyptra. ×14. FIG. 3. Capsule of Grout's 421. ×14. FIG. 4. Capsule of Grout's 467. ×14. FIG. 5. Antheridia and peregonial leaf. ×28. FIG. 6. Enlarged antheridium. ×160. FIG. 7. Enlarged archegonium. ×160. FIG. 8. Enlarged calyptra. ×160. FIG. 9. Cells of apex and awn of stem leaf. ×80. FIG. 10. Cells of the base of stem leaf from midrib to margin. ×80. FIG. 11. Cross section of midrib of stem leaf. ×175. FIG. 12. Cells of apex of capsule in surface view, from Herter's 1212. ×175. FIG. 13. Section of base of capsule wall. ×175. FIG. 14. Section of side of capsule wall. ×175. FIGS. 15–17. Stomata from base of capsule. ×175. FIG. 18. Section of base of capsule wall showing stoma in median view. ×175.

not evident in face view. The outer covering or capsule wall becomes quite wrinkled in drying and is thrown into folds, often with the most conspicuous fold extending over the apex of the capsule, and prolonged soaking or cooking does not completely obliterate the folds. Thus a capsule such as the one illustrated in figure 2 might appear very much like the one in figure 4 if seen from a different angle. The epidermis of the capsule wall presents a very uneven surface due to variations in size and shape of the cells and figure 12 shows the cells at the tip of a capsule from Herter's 1212 where the only evidence of an apiculus is the four cells which are somewhat elevated. The capsule of figure 3 shows several such groups of elevated cells at the top, giving the appearance of a short broad apiculus with the tip cut off. Thus it is very hard to say whether an apiculus is present or not.

The epidermal cells of the capsule wall have a very thick cuticle on the outer surface which is effective in keeping out water, and the wall must be punctured with a needle in order to permit the water to enter when the capsules are soaking. The cuticle of the cells at the base is much thinner and all of the stomata are in this region, sometimes as many as twenty-five on a single sporophyte. The base of the capsule is broad and truncated instead of tapering to the short seta. The stomata are usually of the kind illustrated in figure 15 and consist of one cell, but ring shaped stomata as shown in figure 16 may be found intermingled with the others, and the one illustrated in figure 17 seems to be two celled but it is not certain that the lines extending from the opening are really walls dividing the cell. The capsule wall contains large spaces traversed by filaments of green cells extending to the cells of the spore sac, but cells of the spore sac were never obtained in section for they seem to become disorganized as the spores mature. The base of the capsule wall contains smaller intercellular cavities in contact with the stomata, and consists of more layers of cells than the sides. Free hand sections of the wall are illustrated in figures 13, 14 and 18.

The spore mass does not fill the entire capsule and Müller in 1879 said that it occupied no more than a third of the cavity. Preliminary observations on the relative size of the spore mass indicated that this might be a distinguishing characteristic for the two plants collected in Texas, numbers 421 and 467. The spores fill a much larger part of the capsule in 467 as illustrated in figure 4, than in figure 3 which is of collection number 421. While this difference seemed to be rather constant in these two collections, both conditions were found in different capsules in the same collection of *L. paraguensis*. The number of spores per capsule varied from about 80 to 170 according to counts made on twelve sporophytes from different collections, and the number was not constant in different plants of the same collection.

Spore size seems to be equally unreliable as a character to differentiate species. No measurements of spores were given in the original descriptions of the South American species, but in 1924 Brotherus gave spore size for the five species which he listed as follows: *L. glauca* 150–200 μ; *L. globiceps* 120–130 μ; *L. imbricatum* 100–200 μ; *L. Giberti,* not given; *L. paraguensis* 130–160 μ. For specimens 421 and 467, Grout gave the size as reaching 185 μ and 125 μ respectively. The spores show a great range in size in a single capsule, and measurements were made by the author with the results in microns given below, figures in parenthesis indicating the range in size in a single capsule: *L. paraguensis* (120–125), (125–160), (125–145); *L. Giberti* (120–152), (130–155); Grout's 467 (120–140), (115–130), (120–145); Grout's 421 (130–175), (130–182); other collections from Austin, Texas (100–170), (115–188), (130–155); in *L. globiceps* the spores were quite obviously young and immature and were about 100; immature spores of *L. imbricata* (100–140). There was some evidence of disintegration of spores of small size in capsules which contained many very large spores, but other capsules showed spores of nearly uniform size. The capsules vary from 1 mm. to 1.8 mm. in length, and from .9 mm. to 1.5 mm. in the short diameter. It seems probable that the size of the capsule, the size of the spore mass, the number of spores and the size of the spores are all dependent on the growing conditions.

In his description of *L. paraguensis* Bescherelle states that it differs from *L. glauca* in that the leaves are merely acuminate and lack the long awns. Observations made on the type specimen show that the perichaetial leaves do not have long awns, but the stem leaves have awns reaching .45 mm. in length, while the length of the awns of stem leaves in different collections varied from about .2 mm. to .6 mm. The awns of the perichaetial leaves in different collections showed great variation in length, and because the awn usually ends in a single long cell and is rarely more than two or three cells wide in any part, they are fragile and broken ones have been observed. *L. paraguensis* number 3623 which was collected in the same locality as the type has well developed awns on the perichaetial leaves reaching .8 mm. in length (fig. 2).

Müller gave very little to differentiate the three species which he described. He said that the group of perichaetial leaves around the capsule of *L. globiceps* gives the whole structure a globose shape in contrast to *L. glauca* where it is pointed, and he differentiated *L. Giberti* by saying that it is much smaller than either *L. glauca* or *L. paraguensis,* both of which are more glaucous green. All these characters show great variation and, in the opinion of the writer are too indefinite to be used as differentiating characters of species. However, the types of some of the species have not been seen.

No differences in sex organs, calyptra, rhizoids or vegetative leaves are given as distinguishing characters for species by any authors, and no dif-

ferences have been found in the present investigation. The archegonia are usually apical, and have been found in a large number of the collections, but the plant illustrated in figure 1 shows several archegonia in a leaf axil at some distance from the tip of the stem. The antheridia are found in groups to ten or twelve in number in the axil of a single perigonial leaf a short distance below the perichaetial leaves. Sperms were not found in any of the antheridia but young archegonia with the cover cells intact were found, as well as the mature open ones.

The rhizoids are generally unbranched and consist of a number of cells with the usual oblique cross walls. They are scattered over the stems and are often more abundant on the enlarged areas on the stem which are illustrated in figure 1. These thickened regions may serve as asexual reproductive bodies which are formed in one growing season and develop into leafy stems at a later time. The stems are rather thick and fleshy and are white in color with cells containing stored food, apparently in the form of oil. The plants frequently grow on a thin layer of soil over rocks and when collected the mass of soil and intertwined horizontal stems is put in the envelope as a whole. If this mass is viewed from the under side with the binocular microscope, the branching character of the stem is quite evident, as well as the thickenings on the stems, and the plants can be distinguished from all species of Acaulon very easily. The leaves of Acaulon are usually yellow to yellow brown in color when the capsules are mature, while Lorentziella is glaucous green or whitish when the perichaetial leaves are abundant.

The stem leaves consist of quadrate cells at the base and of hexagonal cells above, all with chloroplasts when young, but the older leaves such as the large perichaetial ones have very few chloroplasts in the cells, especially in the upper part of the leaf. The cells show small but distinct corner thickenings in most of the older leaves. Stem leaves vary from .7 mm. to 1.5 mm. in length without the awn, with the small leaves at the base of the stem and increasing in size toward the top. The perichaetial leaves often reach 3 mm. in length without the awn which varies from .6 mm. to 1 mm. The largest leaves and the longest awns were found on the plants from Texas.

Lorentziella bears a strong resemblance to *Gigaspermum* in the structure of the stem and in the form and color of the leaves, but *Gigaspermum* is without a midrib, and from the limited material at hand, it seemed that the stem leaves of *Gigaspermum* had much shorter awns and were thinner and more delicate in texture. The base of the capsule is quite similar in the two genera both as to shape and structure and distribution of the stomata, but *Lorentziella* shows no evidence of an operculum or of a columella both of which are present in *Gigaspermum*. The columella is not mentioned in the descriptions of the genus, but it was quite conspicuous in capsules of *Gigaspermum repens* (Hook.) Lind. from New Zealand (Hooker's number

1439) in the herbarium of the New York Botanical Garden. Spores from these capsules measured 150 μ to 170 μ. For the same species Lindberg in 1864 gave the spore size as 90 μ, and for the genus, Brotherus in 1924 gave the size as 70 μ.

Lorentziella has been found in Uruguay, Paraguay and Argentina between the 25th and 35th parallels with the majority of the collections nearer the 35th parallel. With the exception of the collections at Cordoba, it was found relatively near the coast or along the Plata River. It has been found in six counties in Texas, ranging from Cameron County on the Mexican border and the Gulf of Mexico in the vicinity of the 26th parallel north latitude to the five counties farther north which are all near the 30th and 31st parallels and at a distance inland. *Gigaspermum* has been found in New Zealand, Tasmania, Australia, Morocco and South Africa. The other genera of the family, *Oedipodiella* and *Chamaebryum* are known only from South Africa.

From this study of all the material available, the conclusion is that all collections examined belong to one species, *Lorentziella imbricata* (Mitt.) Broth. It is exceedingly interesting to find a moss in the United States belonging to a family known only from the Southern Hemisphere and Morocco, and to learn that ten different collections were made in Texas, the earliest in 1919 by Professor McAllister.

The writer is very grateful to Dr. T. C. Frye who provided the specimen which initiated this investigation, to Dr. H. S. Conard for assistance and suggestions and to the Lakeside Laboratory of the State University of Iowa where the work was begun. The writer also wishes to express thanks to Dr. D. P. Rogers and Miss Rosalie Weikert of the New York Botanical Garden, to Mr. E. B. Bartram, and to the curators of all the herbaria named above for the specimens which were loaned.

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CYTOLOGIC EVIDENCE FOR THE OCCURRENCE OF CELLULAR AND NUCLEAR FUSION IN BACILLUS MEGATERIUM[1]

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The early extensive studies of Mellon (1925) and subsequently of Dienes (1946) on numerous organisms have indicated that cellular fusion between bacteria suggestive of a sexual process does occur. Mellon showed that specialized cellular structures may fuse in certain bacteria with the production of structures reminiscent of what have been visualized in certain of the yeast-like fungi such as *Endomyces*.

The recent studies of Stempen and Hutchinson (1951a, 1951b), in which they confirm and extend the original observations of Wyckoff (1933) by means of time-lapse movies, indicate clearly that cellular fusion in *Proteus vulgaris* occurs with the formation of so-called "large bodies." These authors indicate two other methods whereby large bodies may be produced, namely, (1) by a process of budding, in which a bud-like structure appears at one side or at one end of the bacterial rod and then gradually increases in size at the expense of the rod, and (2) by a process of swelling in which the rod produces a distinct rounded bulge which increases in size and subsequently incorporates the remainder of the rod into itself. These observations also extend those made by Dienes (1946) on the same organism a few years earlier.

It seems unnecessary at the present time to attempt to survey the literature completely on the formation of large bodies in bacteria. The purpose of the present paper is to present cytologic evidence for the occurrence of cellular fusion in *Bacillus megaterium* by means of a distinctive conjugation tube. A consideration of the conditions which induce the conjugation process is presented separately (DeLamater 1951a–c, DeLamater and Hunter 1952).

Materials and methods. The strain of *Bacillus megaterium* used in these studies was obtained from Dr. A. G. Smith. For the purposes of these studies the organism has been grown on blood agar base containing 4 or 5 percent human blood.

The cytologic procedures utilized are those of DeLamater, 1951b. These have been given in detail in the original paper and in various studies on mitosis in this and other bacteria (DeLamater 1951a, 1952a, and DeLamater and Hunter 1951, DeLamater and Mudd 1951).

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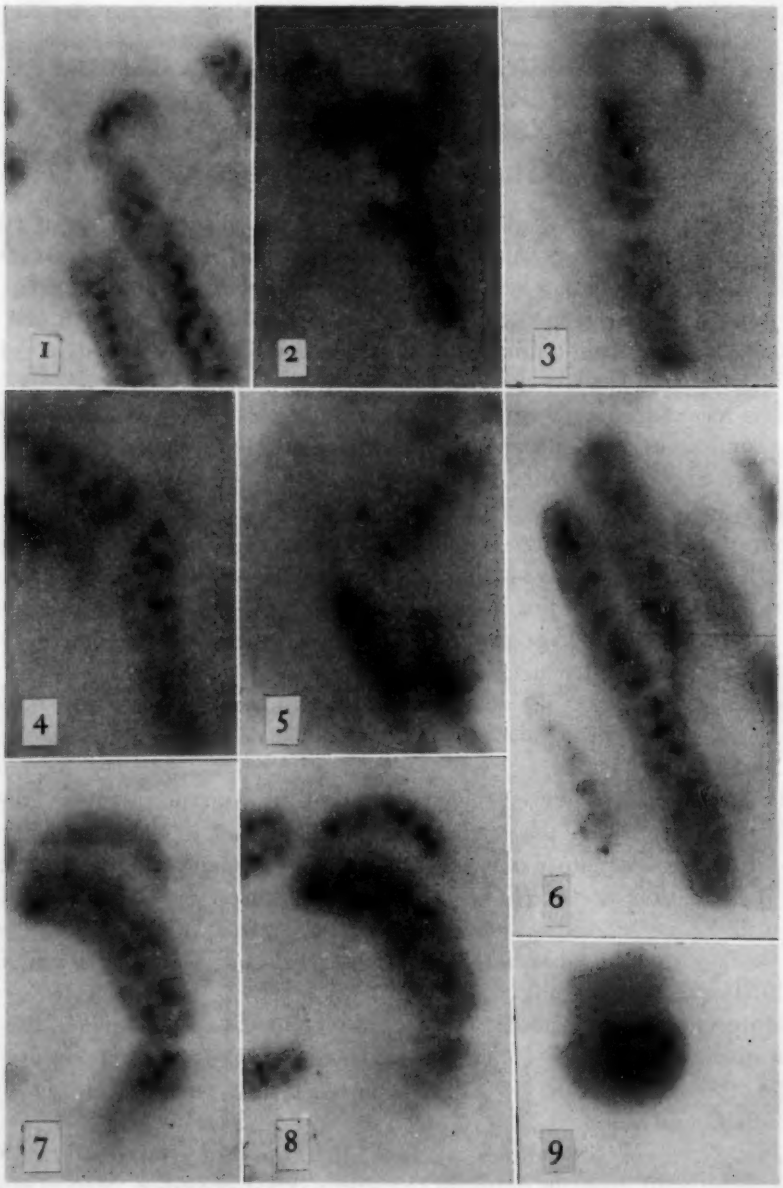


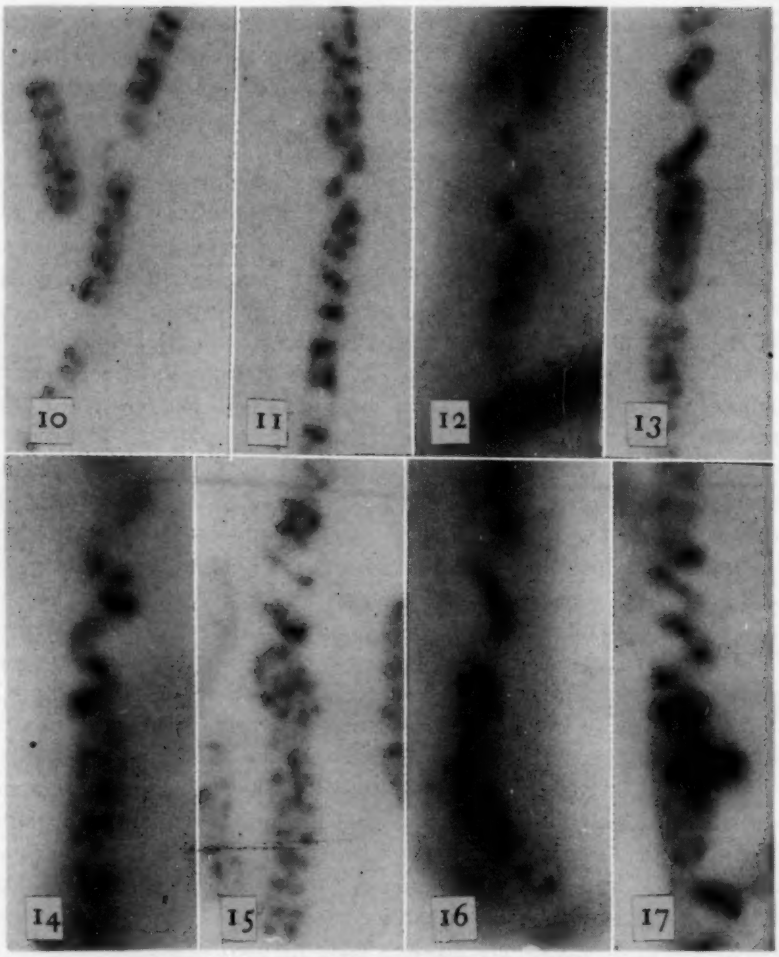
FIGS. 1–9. Photomicrographs of *Bacillus megaterium* ×4450. FIGS. 1–3. Early unfused conjugation tubes. Note condensed chromatinic material. FIGS. 4–5. Early stages in fusion by means of delicate conjugation tubes. Both instances demonstrate fusion into lateral sides of cells. FIG. 6. Fusion tube from tip of one cell into lateral side of adjacent cell. Example shows conjugation tubes cannot be confused with plasmodesmids. FIGS. 7–8. Two focal planes through same bacillary rod from one end of which a conjugation tube has twisted back to fuse with second cell in rod. FIG. 9. Transverse optical section through large diploid cell showing central position of nucleus and the peripheral position of the chromosomes in the nucleus dying adjacent to the nuclear membrane.

Observations. Figures 1 to 3 demonstrate vegetative cells to which are attached curved structures interpreted as conjugation tubes. These characteristically are formed at the tips of cells, but may, as will be presently seen, occur from other portions of the cells. In figures 4 and 5 are shown early union between adjacent cells by means of these delicate tubes. It is apparent that these tubes are not so-called plasmodesmids which form at the time of crosswall formation which separates two cells within a rod. Plasmodesmids characteristically occur at the center of the constricting wall and in the axial center of the cell. Figure 6 demonstrates the fusion by means of a delicate conjugation tube of one cell lying parallel to the cell to which it is fused. It also demonstrates conclusively that this cannot be a plasmodesmid since the other half of the fused rod is still attached and lies immediately parallel and adjacent to the fusing cell. Figures 7 and 8 demonstrate two optical planes through the same enlarging cell from one end of which is a retroversely curved conjugation tube observed to be in the process of fusing with the other half of the rod at a lowest focal plane. Figure 9, for purposes of completion of description of the plate, demonstrates the central position of the large nuclei in the enlarging large cells.

In figures 10 to 17 are demonstrated several configurations of the spiral conjugation tubes which are fused end to end with other cells. In figures 11 to 17 can be seen evidence for the migration of nuclear elements within these conjugation tubes and from one cell to another. It is also apparent that following fusion there is a progressive enlargement of the fused cells from two to four times the original size.

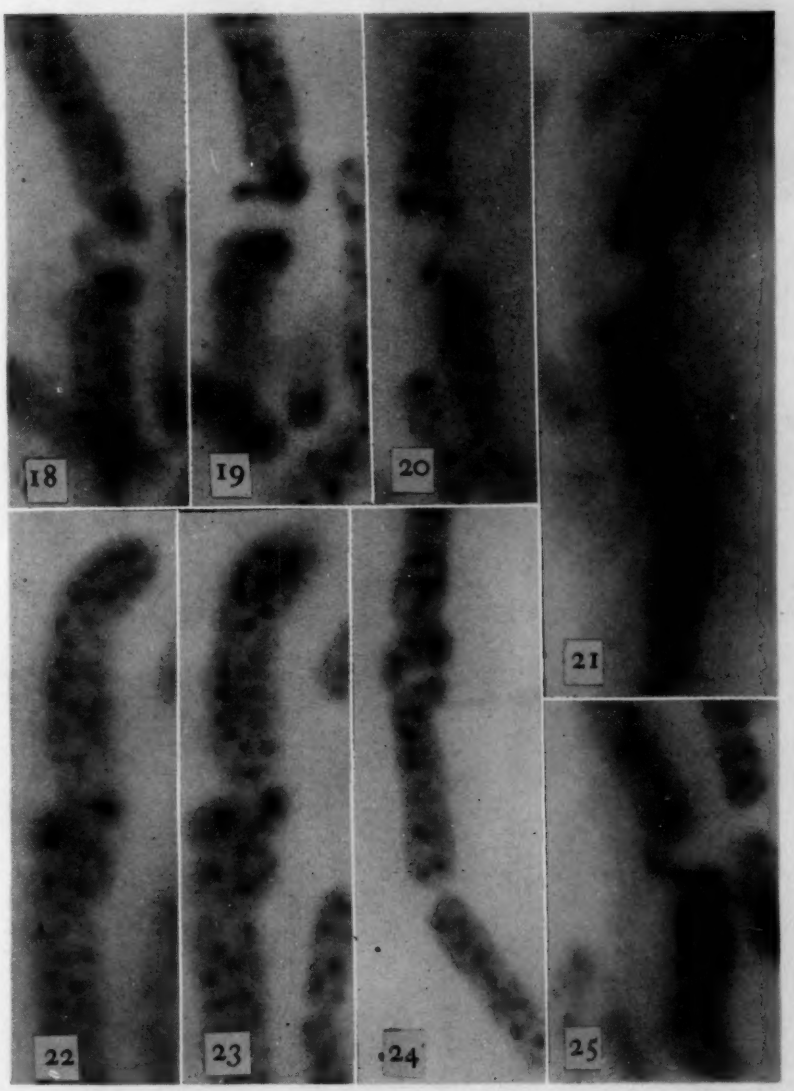
Figures 18 to 25 demonstrate later stages of the fusion process by means of these conjugation tubes. Figures 18 and 19 show two much enlarged cells joined by a spiral conjugation tube within which lies a dense chromatin mass. Figures 20 and 21 further demonstrate the spiral character of these conjugation tubes and the marked enlargement of the cojoined cells. Figures 22 and 23 are optical sections through such a fused cell in which the conjugation tube is obviously very complex and within which in the left-hand side of figure 22 a telophase stage of a nuclear division may be seen. In figure 24 the fusion has apparently been double with the formation of two simultaneous conjugation tubes between the two cells.

In figures 26 and 27 are demonstrated two optical planes through the same fused cells. At the upper pole in figure 26 can be seen nuclei in telophase division. The three chromosomes of the lower sister nucleus are in a row, and apparently migrating into the conjugation tube, as shown in figure 27. The lower joined cell, as shown in figure 27, is enlarging with increasing complexity of the contained nuclei. In figure 28 is seen similar fusion by means of a conjugation tube. Within the conjugation tube are seen what are interpreted as the three chromosomal granules (vegetative haploid

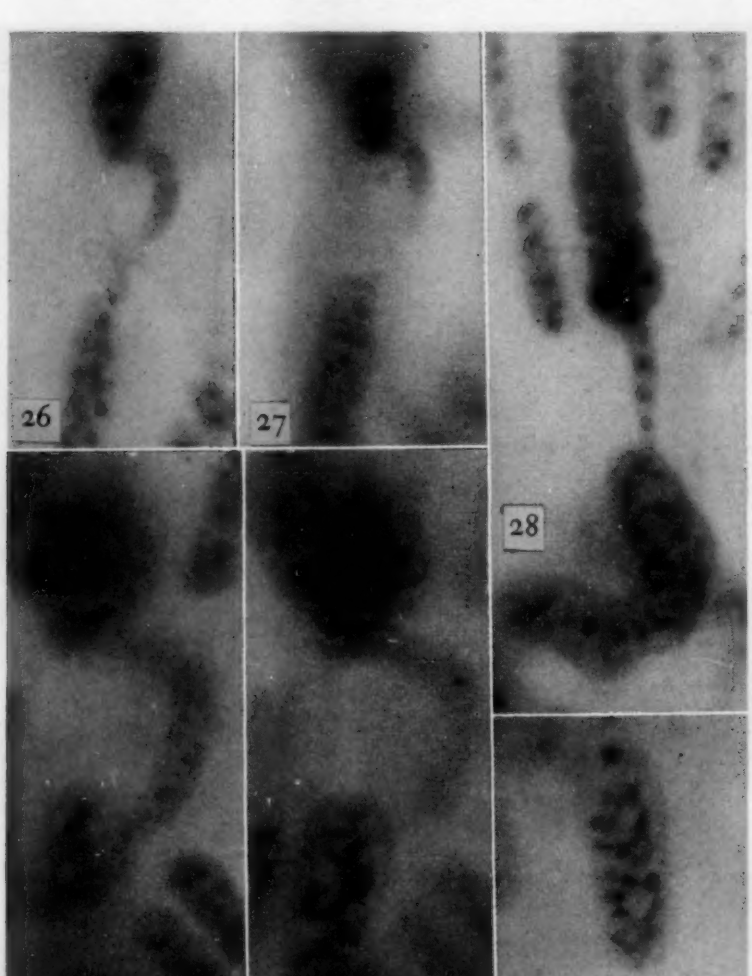


FIGS. 10–17. Photomicrographs of *Bacillus megaterium* ×4450. FIGS. 10–11. Very early fusion stage between two vegetative cells. Nuclei of haploid size and configuration. Conjugation tubes between ends of cells. FIGS. 12–14. Later stages in development of terminal conjugation tubes. Typically spiral character well shown. Nuclear material present in tubes interpreted as in migration. FIG. 15. Spiral conjugation tube between smaller upper cell and larger lower cell. Nucleus in upper cell haploid; large nucleus in upper end of lower cell more complex and interpreted as diploid. FIGS. 16–17. Later additional examples of spiral conjugatiaon tubes containing migrating nuclei.

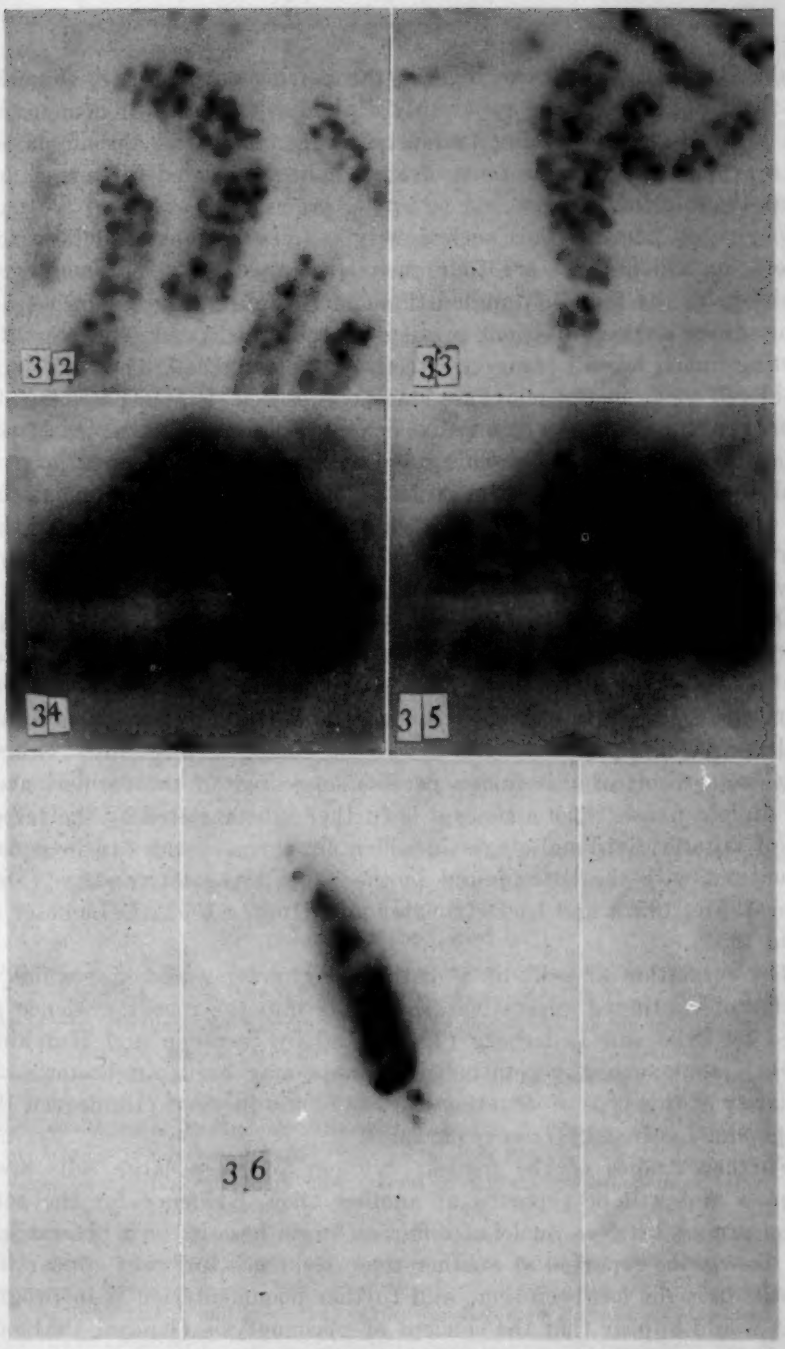
number) apparently in migration from the upper to the lower cell. The nuclei in the lower cell demonstrate a considerable complexity, and other focal planes to be presented elsewhere (DeLamater 1951c) demonstrate the pairing and elongation of the chromosomes in the upper part of the lower cell. Figures 29 and 30 again present two optical sections through the same



FIGS. 18–25. Photomicrographs of *Bacillus megaterium* ×4450. FIGS. 18–19. Two optical planes through same fused cells showing condensed nuclear material in spiral conjugation tube. Joined cells enlarging. FIG. 20. Later stage in conjugation; joined cells enlarging. FIG. 21. Still later stage. Upper cell appears to be devoid of nuclei. Nucleus in spiral tube. Nuclei in lower cell large and complex. FIGS. 22–23. Two optical sections through same fused cells. Nuclei in large spiral tube (fig. 22) appear to be in telophase. FIG. 24. Double fusion tubes between two cells. FIG. 25. Additional example of spiral tube showing range variation in the configurations observed.



FIGS. 26–31. Photomicrographs of *Bacillus megaterium* ×4450. FIGS. 26–27. Two optical sections through same fused cells. In upper cell haploid nucleus is in telophase stage of division. Three haploid chromosomes visible in each sister nucleus. In figure 27 three chromosomes in row appear to be migrating into tube. FIG. 28. Conjugation tube between two large cells. Three condensed chromosomes of migrating haploid nucleus visible in tube. FIGS. 29–30. Two optical sections through same fused cells. Figure 30 in lower cell the large chromosomes of diploid nucleus are visualized. FIG. 31. Large diploid cell showing two large diploid interphase nuclei in which chromosomes occur as long tangled threads.



FIGS. 32–36. Photomicrographs of *Bacillus megaterium* × 4450. FIG. 32. Large diploid cell showing four very large diploid interphase nuclei in which chromosomes occur as long, delicate, beaded threads. FIG. 33. Large diploid cell in which nuclei are in telophase stage of mitotic division. In each chromosome cluster six chromosomal granules (condensed chromosomes) could be counted. Compare with figure 36. FIGS. 34–35. Two optical planes through a cluster of very large diploid cells. FIG. 36. Photomicrograph of *Bacillus megaterium* × 4450. Late telophase in large haploid cell showing each set of three chromosomes migrating toward the persistent centrioles. The spindle fibers are visualized. The characteristic rotation of the sister nuclei as they separate is also shown.

fused cells. In figure 30 can be seen the pairing chromosomes elongating into filaments in the large apparently diploid cell. Figure 31 demonstrates such a large cell containing two very large nuclei, the chromosomes of which are obviously in the form of long, delicate, beaded threads, tangled within the nucleus.

Figure 32 demonstrates such a very large cell, construed here to be diploid, in which there are four such large nuclei, the chromosomes of which are in the form of tangled threads. In figure 33 are shown several simultaneous nuclear divisions in such a large diploid cell. The axes of the dividing nuclei are all transverse to the axis of the cell. These nuclei are considered to be in the telophase stage of division. It was possible in the original preparation to count six discrete chromosomes in each sister nucleus of a dividing pair. This stage of nuclear division in a large cell should be compared with figure 36 in which is shown a late telophase division in a large haploid cell in which the three chromosomes can be readily counted. In figures 34 and 35 are demonstrated two optical planes through the very large and very complex diploid cells.

Discussion. The evidence presented here suggests that in *Bacillus megaterium*, at least, cellular fusion is accomplished by means of delicate conjugation tubes suggestive of a process a little more specialized than that described in *Proteus vulgaris* by Stempen and Hutchinson (1951a and b). Evidence is also presented for the formation of tremendously enlarged nuclei as a result of this fusion process suggestive of the formation of a true diploid phase. Such a concept is further substantiated by the recognition of mitotic divisional stages in which six chromosomes can be counted in contrast with the three found in the haploid vegetative stage (DeLamater 1951c, 1952a and b; DeLamater and Hunter 1951; DeLamater and Mudd 1951).

The formation of cells of a distinctive character and size which are capable of continued vegetative growth fits into the recent evidence produced by Zelle and Lederberg (1951), and by Stempen and Hutchinson (1951a), that such a vegetative diplophase may occur in bacteria. The similarity of this type of situation to what occurs in yeast (Lindegren 1949, Wingë and Lausten 1937) is remarkable.

Further studies of the nuclear cytology of these large cells are in progress and will be reported at another time. Evidence for the actual fusion process between nuclei of different origin has also been observed and will likewise be reported at another time. Evidence for what appear to be meiotic divisions has been seen, and further documentation is in progress.

It would appear that the concept of plasmoptysis (Knaysi 1951) does not apply to the phenomena described.

Preliminary study of the chemistry of the conditions which induce for-

mation of these conjugation tubes is in press (DeLamater and Hunter 1953).

From the point of view of the biologist familiar with the various configurations of the sexual process in many microorganisms it should not be surprising that sexuality occurs in the bacteria, nor that it takes distinctive and recognizable patterns. The hesitancy that Stempen and Hutchinson exhibit in using the word, "sexuality," in describing the phenomena which they have observed is commendable, but probably not necessary in the face of the vast amount of evidence that has been accumulated on other forms (Kniep 1928, Guillermond 1920).

In view of the large amount of information which has been accumulated concerning sexual processes in microorganisms, it seems unjustified to limit as acceptable only genetic evidence of recombination. The ideal situation would be to achieve simultaneously cytologic, genetic, and biochemical evidence on the sexual processes of a single organism.

SUMMARY

1. Evidence for the occurrence of cellular fusion by means of conjugation tubes in *Bacillus megaterium* has been presented with the concomitant development of greatly enlarged and probably diploid nuclei.

2. The process is interpreted here as sexual, and because of the observation that unrelated cells, i.e., non-sister cells, can partake in the process, it seems likely that it will be possible to produce evidence to substantiate the cytologic evidence.

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THE SPORANGIAL PHASE OF THE DOWNY MILDEW ON ELEUSINE CORACANA WITH A DISCUSSION OF THE IDENTITY OF SCLEROSPORA MACROSPORA SACC.

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The downy mildews of cereals and grasses incited by species of *Sclerospora* are now recognized as destructive diseases which often cause very serious losses. Some species of *Sclerospora* cause a shredding of the leaves; other species cause a proliferation of the spikelets into leafy structures; few species incite both types of symptoms. *S. graminicola* causes shredding of leaves on *Setaria* spp., while on *Pennisetum typhoideum* it causes marked proliferation of the spikelets and but little shredding. Oospores typical of *Sclerospora* spp. are characteristically embedded within these deformed tissues. While the presence of the sporangial (conidial) phase of these fungi is necessary for positive identification of the pathogen as a species of *Sclerospora,* frequently the presence of oospores only, together with characteristic host symptoms, has been considered sufficient basis for assigning the fungus to *Sclerospora.* The asexual phase in *Sclerospora* is but rarely observed because of its evanescent nature. In all the species so far studied the asexual stage is produced under natural conditions only during the early hours of the morning, and then only if there is sufficient dew on the surface of the leaves. Since the sporangiophores (conidiophores) gelatinize and collapse immediately after discharge of the sporangia (conidia), fungi exsiccati are of no value in studying the asexual phase of species of *Sclerospora.*

Study of fresh material of the sporangial (conidial) stages has increased our knowledge of species assigned to *Sclerospora* and has necessitated changes in the status of certain species. For instance the downy mildew on *Eragrostis* spp. was described as *Sclerospora butleri* by Weston (1933) on the basis of the resting spore stage and the disease symptoms. However, the sporangial phase of the fungus revealed it to be a species of *Basidiophora* (Thirumalachar & Whitehead 1952).

Interest in *Sclerospora macrospora* Sacc. was aroused following the discovery by Peyronel (1929), Peglion (1930), and Tanaka (1940) that the sporangial stage is like that of *Phytophthora.* In the present study the authors have been able to observe in detail the sporangial stage of *Sclerospora macrospora* on finger millet, *Eleusine coracana* Gaertn. An account of these observations and their bearing on the identity of the fungus is presented in this paper.

Effect of the host. *Eleusine coracana* is an important cereal in several

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parts of India. It is grown both as an irrigated and non-irrigated crop. The downy mildew disease is encountered chiefly in the irrigated crop during November and December. An account of the disease symptoms was presented in a previous paper (Thirumalachar & Narasimhan 1949). The fungus incites proliferation of the spikelets into leafy structures, often involving the entire ear heads and converting them into brush-like structures. No shredding of the leaves has been noticed. The disease builds up in severity if the crop is grown successively in fields where the disease has been present in previous years.

Characteristics of the fungus. Oogonia and oospores. The morphology of the antheridia, oogonia, and the oospores has already been described (Thirumalachar & Narasimhan 1949). The oogonial initials were formed as swellings of the apices of the thick hyphae. The antheridia were paragynous and formed in close juxtaposition with the oogonia. Fertilization stages have not been observed. McDonough (1946) gives a detailed cytological account of gametogenesis and oospore formation in this downy mildew on wheat. Oospores have not been germinated in the present study, but Peglion (1930) described and illustrated their germination by sporangia, formed either directly from the oospore or borne on a sporangiophore.

Initial sections through proliferated spikelets of *Eleusine coracana* revealed that oospores were sparsely distributed in these tissues and could be obtained only with difficulty. However, after the diseased crop was harvested in a field near Bangalore, new tillers developed which were stunted and considerably yellowed. Examination of the leaves and spikelets of these tillers showed innumerable oogonia and oospores within the mesophyll tissue. Comparison of the fungus on *Eleusine coracana* with authentic material of *Sclerospora macrospora* Sacc. on wheat and corn convinced the writers that the two are cospecific.

Sporangial phase. Diseased specimens of *Eleusine coracana* were collected during daylight hours in early November when the spikelets showed early stages of proliferation into leafy shoots. Since the symptoms produced on the host were like those caused by *Sclerospora,* attempts were made to find the sporangial stage. Microscopic examination revealed the presence of thin-walled, contorted hyphae between the vascular bundles and the mesophyll but sporangia were not seen. Proliferated spikelets were then sprayed with water from an atomizer and inclosed in a moist chamber in the evening and periodically examined between 1 A. M. and 4 A. M. Macroscopic observations failed to reveal the presence of downy outgrowths on the diseased spikelets. However, when scrapings of the ventral surface of the spikelets were examined under the microscope, numerous large lemon-shaped sporangia were found. Several of these had germinated by the for-

mation of zoospores, so that the droplet of water contained innumerable actively motile zoospores.

Further studies indicated that under laboratory conditions there was no periodicity in the production of sporangia in this species. Instead, the sporangia were found to develop whenever infected tissue was incubated at high humidities and at a temperature between 60 and 68° F. Under these conditions sporangia were produced in the tiny droplets of water which condensed on the diseased host parts. When incubated, the yellow leaves taken from diseased tillers produced abundant sporangia and provided suitable material for the study of the sporangial phase.

The following technique was adopted to study the developmental stages of the sporangia. Small fragments of the proliferated spikelets or of leaves from the diseased tillers were floated on sterile distilled water in Petri dishes or on hanging drop glass slides and periodically examined under the microscope. Sporangial formation occurred after four to five hours' incubation, by which time sufficient water had condensed on the exposed surface of the host to provide a film. No sporangial development was observed from diseased parts of the host that were in contact with the water or that were completely submerged. Sporangial formation was observed only in the portions of the host just above the surface of the water or on portions of the host where there was heavy condensation of moisture.

The first stage in the development of a sporangium is the extrusion of a hyphal branch through the stoma from the contorted hyphae grouped beneath the stoma (fig. 1). This external hypha is about 10 to 15 μ long and identical in shape and structure with the hyphae within the host. This unaltered hypha functions directly as the sporangiophore, a large lemon-shaped sporangium developing at the apex (fig. 1). The fragile sporangia are very loosely attached and the slightest disturbance separates them from the hyphoid sporangiophores. Consequently it was extremely difficult to observe or photograph them in actual contact with the host tissue, even though hundreds of them were being formed successively. However, when the culture mount was carefully handled to avoid any disturbance, the full picture of sporangial development became evident. The hyphoid sporangiophore first produces a large sporangium at the apex, which in due course germinates by the formation of an apical pore, releasing 24 to 32 zoospores. Meanwhile two lateral branches are formed, one on either side of the main axis. These in their turn develop similar lemon-shaped sporangia apically (fig. 2). There is thus a sympodial branching of the sporangiophore, with the sporangia at different stages of maturity. By further division of the lateral branches, a cluster of four to five sporangia is formed (fig. 3). Mature sporangia are large, lemon-shaped, with an apical papilla and a pedicel-like hypha at the base. They measure 60–100 × 43–64 μ.

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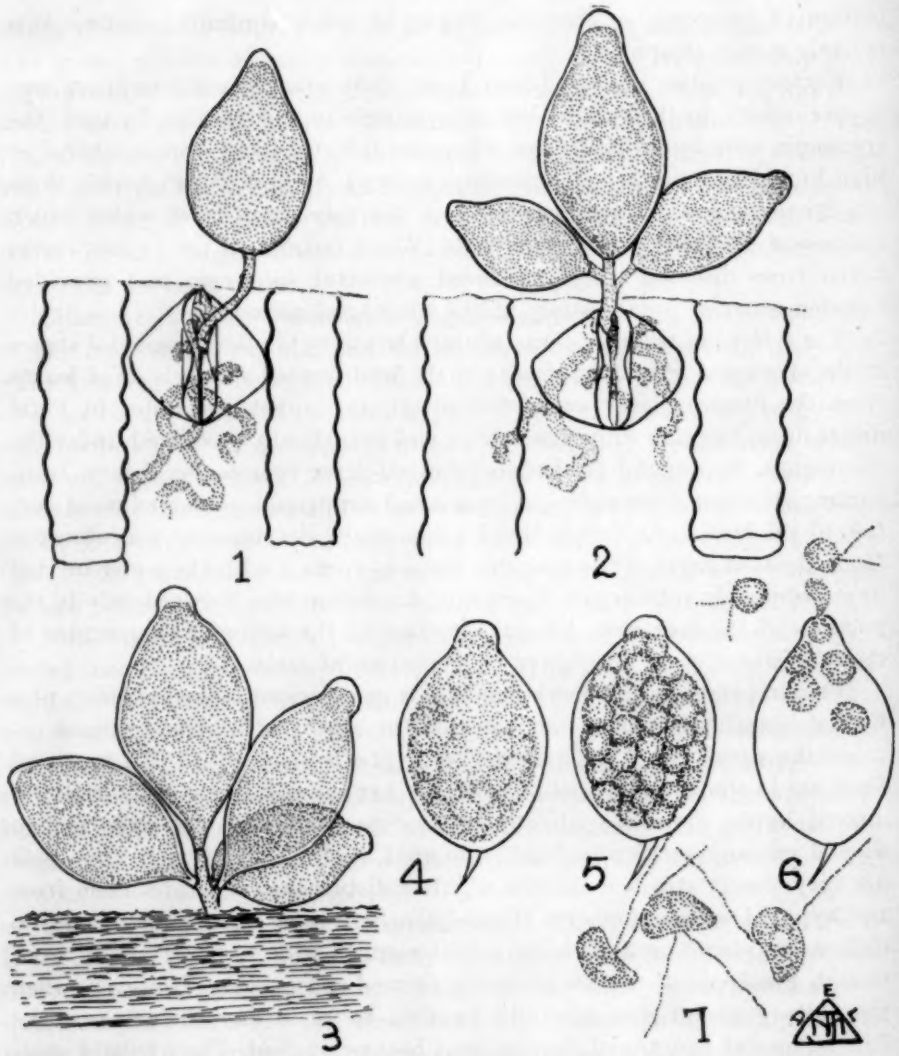

FIGS. 1 & 2. Formation of sporangia on hyphoid sporangiophores ×475. FIG. 3. Sympodial cluster of sporangia ×475. FIGS. 4–6. Stages in zoospore formation ×475. FIG. 7. Zoospores ×950.

Mature sporangia germinate within a few hours after their formataion. When provided with abundant moisture and incubated at room temperature (68 to 80° F.) their contents divide and round off into 24 to 32 zoospores (figs. 4 to 6). After their differentiation, the zoospores perform rotating movements within the sporangium and finally escape through the apical

pore (fig. 6). The zoospores are subspherical to reniform. Preparations stained with Noland's staining solution reveal their biciliate condition. After a period of motility the zoospores lose their cilia, develop a membrane and germinate by a delicate germ tube. When the sporangia were spread on 2% water agar, in the absence of a moisture film, several of them germinated directly by developing germ tubes. Tanaka (1940) reported similar direct germinations in the downy mildew of wheat.

Identity of the fungus. *Sclerospora macrospora* was described by Saccardo in 1890 for the oospore stage of a downy mildew on the inflorescence of *Alopecurus* sp. collected in Australia by Tepper. The fungus has been shown to have a wide host range including several cultivated graminicolous hosts such as barley, corn, oats, rice, rye, wheat, etc., and many wild grasses. The fungus has been studied in some detail in the United States, Europe and Japan. Arnaud (1915) described the malformation of the spikelets of wheat in France due to the downy mildew and illustrated the formation of the oospores around the vascular bundles. Weston (1921) and later Miles & Epps (1942) recorded the occurrence of this downy mildew on wheat and oats in the southern and southeastern parts of the United States and pointed out its potential menace.

The discovery of the Phytophthora-like conidial state in the downy mildew of rice by Tasugi in 1927 (cf. Tanaka 1940), and later by Peyronel (1929) and Peglion (1930) on wheat in Italy aroused renewed interest in this fungus. Both Peyronel and Peglion described the development of large lemon-shaped sporangia which resembled those of *Phytophthora* and which germinated by zoospores. In addition Peglion germinated the oospores and described the formation of the same type of sporangia, germinating by zoospores, as occurred in the asexual stage.

The characteristic symptoms produced by the fungus on the host (proliferation of the spikelets and thickened leaf tissue) and oospores with double wall layers (the outer one being the oogonial wall confluent with the exospore of the oospore) led most investigators to regard this fungus as a typical *Sclerospora*. The discovery of the sporangial stage and oospore germination by Peglion was either received with skepticism or disregarded in relation to the classification of the fungus. Tasugi (1931, cf. Tanaka 1940) on the basis of the sporangial stage which he discovered on rice, transferred the fungus from *Sclerospora* to *Nozemia* Pethybr., a genus originally established by Pethybridge (1913) for species of *Phytophthora* with a paragynous type of sexual reproduction. Later *Nozemia* was reduced to synonymy with *Phytophthora*. Tanaka (1940), taking into consideration the morphological characteristics of the sporangial stage, concluded that the causal organism inciting the downy mildew of wheat belonged to *Phytophthora* and transferred it to this genus under the binomial *P. macrospora* (Sacc.) S. Ito

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& I. Tanaka. He failed, however, to recognize the important characters that distinguish this fungus from species of *Phytophthora*. McDonough (1946) in his cytological studies of *Sclerospora* on wheat rightly points out that the thick oogonial wall alone would seem to exclude the fungus from *Phytophthora*. The description of *Phytophthora erythroseptica* (Murphy 1918), which is amphigynous, and that of *P. cactorum* (Blackwell 1943), which is paragynous, clearly indicate the thin-walled nature of the oogonium in *Phytophthora* spp. In the process of gametogenesis and oospore formation, McDonough found that the oospores are multinucleate in *Sclerospora macrospora* as are those of *Albugo* (*Cystopus*) *tragopogonis* (DC) Gray. Thirumalachar, Whitehead and Boyle (1949) and Damle (1943) have reported that in *Albugo evolvuli* (Damle) Saffee., the oogonial wall is confluent with the exospore of the oospore, a character reminiscent of *Sclerospora*.

The morphology of the asexual stage and the method of oospore germination in the fungus under study differentiate it from *Sclerospora*. Oospore germination in *Sclerospora graminicola* (Sacc.) Schroet., the type species of the genus, is direct, by the development of a germ tube, while in *Sclerospora macrospora* germination of the oospore is indirect, by the formation of a sporangium. Even though our knowledge of the oospore germination in the Peronosporaceae as a whole is very meager, the method of oospore germination constitutes a very important taxonomic character. From the above considerations it is evident that the fungus under study possesses the conidial characters of *Phytophthora,* oogonial and oospore characters of *Albugo* and *Sclerospora,* while the symptoms produced on the host are like those caused by species of *Sclerospora*. McDonough (1946), who studied this fungus cytologically, concluded that *Sclerospora macrospora* could not be placed in any known genus and that further work might lead to the erection of a new genus. This study of the sporangial phase of the fungus has disclosed supporting evidence for this view, and the authors therefore propose to place this fungus under a separate genus, having characters of *Sclerospora* and *Phytophthora.*

Sclerophthora gen. nov. Mycelium parasitic in higher plants, hyaline, coenocytic; sporangial stage *Phytophthora*-like; sporangiophores hyphoid, very little differentiated from the hyphae within the host, simple or sympodially and successively branched; sporangia large, lemon-shaped, apically poroid, borne singly at the apices of the sporangiophores, germinating in water by the division of the cell contents into biciliate zoospores.

Oogonial stage like that of *Sclerospora;* oogonial wall thickened and confluent with the wall of the oospore. Ooospore germination indirect, by sporangial formation.

TYPE SPECIES: **Sclerophthora macrospora** (Sacc.) comb. nov. Syn. *Sclerospora macrospora* Sacc.

Mycelium parasiticum in plantis superioribus, hyalinum, coenocyticum;

status sporangialis similis Phytophthorae; sporangiophori haud multum a mycelii hyphis distinctum, simplices vel sympodice et ex ordine ramosi; sporangia ampla, hyalina, pomo limoneo similia in figura, singula insidentia in apice sporangiophori, per divisiones plasmate cellulae in biciliatas zoosporas germinantia. Status oogonialis similis Sclerosporae, parietes oogonialis crassi atque confluentes cum pariete oosporae. Germinatio oosporae indirecta, per formationem sporangiorum.

Species typica: **Sclerophthora macrospora** (Sacc.) comb. nov. Syn: *Sclerospora macrospora* Sacc., Hedw. 29: 155. 1890. *Sclerospora kriegeriana* Magnus, Verh. Deutsch. Naturf. 67: 100. 1895. *Sclerospora oryzae* Brizi, Natura, Milano 10: 168–190. 1919. (Fide Saccardo, Syll. Fung. 24: 65. 1926). *Nozemia macrospora* (Sacc.) Tasugi, 1931. (Fide Tanaka, Ann. Phytopath. Japan 10: 135. 1940.) *Phytophthora macrospora* (Sacc.) Tanaka, Ann. Phytopath. Japan 10: 135. 1940.

Tanaka (1940) in his concluding remarks pointed out, having compared the conidia (sporangia) and oospores formed on wheat and rice plants with those on other affected cereal crops and wild grasses, that it is manifest that *Sclerospora macrospora* Sacc., *S. Kriegeriana* Magn. and *S. oryzae* Brizi are all one and the same species.

Discussion. Study of the sporangial and oosporic stages of the downy mildew formerly classified as *Sclerospora macrospora* Sacc. has shown that the fungus should be assigned to a new genus. While the oogonial and oosporic stages resemble those of *Sclerospora* and some species of *Albugo*, the sporangial phase resembles in structure and development that of *Phytophthora*. In all the members of the Peronosporaceae, the development of the sporangiophore (conidiophore) is determinate, while in the members of the Pythiaceae development of the sporangiophore is indeterminate. In *Sclerophthora macrospora*, the formation of a cluster of sporangia up to five in number by successive branchings of the sporangiophore shows its indeterminate nature, as in the Pythiaceae. *Sclerophthora macrospora* therefore appears to be an intermediary form bridging the Pythiaceae and Peronosporaceae.

Review of the literature discloses numerous reports by different workers of abnormalities in the cereals and grasses, e.g., vivipary, proliferation of spikelets, "crazy top" formation, etc., ascribed to teratological phenomena or abnormal growth conditions. Lai-Yung Li (1950) for instance recently reported vivipary in *Setaria viridis* and *Eleusine coracana* from China. His illustration of a proliferating spikelet of *Eleusine coracana* is very similar to the illustration of a spikelet infested with *Sclerophthora macrospora* published by Thirumalachar and Narsimhan. Crazy top of corn reported by Koehler (1939) and Wernham (1948) is of interest since the disease was reported to be severe in restricted areas and favored by poor drainage in the soil. Ullstrup (1950) has demonstrated the presence of

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coenocytic mycelium and oospores typical of *Sclerophthora macrospora* in corn plants affected with crazy top.

Sclerophthora macrospora usually has been found associated with localities of high soil moisture and poor drainage. Arnaud (1915) in France and Tanaka and others in Japan, reported the occurrence of this disease in wheat fields after flooding. Collections of this fungus have been made by two of the writers in Mysore on the grasses, *Elytrophorus spicatus* A. Camus. and *Saccolepis interrupta* Stapf. which are inhabitants of marshy regions.

Oswald and Houston (1951) recently reported the presence of a downy mildew on barley in California. Although only *Sclerophthora macrospora* had been reported previously on this host, they tentatively identified the fungus as *Sclerospora graminicola* since the oospores in their material measured but 20 μ in diameter and hence agreed more closely with those of *Sclerospora graminicola* (oospores 28–43 μ in diameter) than with those of *Sclerophthora macrospora* (oospores 60–65 μ in diameter). This report is of interest since they mention having observed an "abortive" sporangial stage.

While the sporangial stage of *Sclerospora graminicola* has been observed frequently in the United States, this stage of *Sclerophthora macrospora* has not been reported by other American workers. However Dr. A. J. Ullstrup has shown one of us photomicrographs of cross sections of corn leaves infected with crazy top. These photomicrographs show what appear to be remnants of sporangiophores in the stomata and oospores in the mesophyll. The material was collected at about eight o'clock in the morning and suggests that the sporangial stage has been missed by other workers because collections have not been made between midnight and dawn.

Under natural conditions sporangial production in *Sclerophthora macrospora* and *Sclerospora* spp. occurs only between midnight and dawn. It is only during these hours that moisture and temperature relationships are favorable for asexual reproduction. Our results indicate that in *Sclerophthora macrospora* at least there is no periodicity inherent in the fungus itself. Similar experiments with species of *Sclerospora* would determine whether or not nocturnal production of sporangia (conidia) in this genus is an example of true periodicity.

In conclusion the writers wish to acknowledge their indebtedness to Dr. James G. Dickson, Professor of Plant Pathology, University of Wisconsin, Madison, for the benefit received from many valuable suggestions.

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BULLETIN OF THE TORREY BOTANICAL CLUB
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ON THE MORPHOLOGY AND REPRODUCTION OF CHARACIUM SACCATUM FILARSKY[1]

RICHARD C. STARR

Of the many species of *Characium* which have been described in the literature, comparatively few have been studied in any great detail. Although the process of zoospore production in *Characium* was described as early as 1855 by Braun, the cytological details of the process were unknown until Smith's (1916) work on *Characium Sieboldii* A. Br. In this species, the vegetative cells are multinucleate at maturity; zoospores are produced as a result of progressive cleavage of the multinucleate protoplast. Carter's (1919) study of *C. angustum* A. Br. showed a second method by which zoospores may be produced. In this species, according to Carter, the vegetative cells never become multinucleate; a bipartition of the protoplast immediately follows each mitotic division of the nucleus. In the present investigation of *Characium saccatum* Filarsky, the writer describes a third type of nuclear condition in which the vegetative cells, although uninucleate at maturity, become multinucleate immediately preceding cleavage, which is, therefore, of the progressive type.

Details of the sexual process in *Characium* are less well known than those of the asexual process. Schiller (1924) described the production and pairing of gametes of *Characium limneticum* Lemm., but, as Kniep (1928) points out, the uniflagellate gametes of Schiller's alga would seem to indicate that it belonged to the Xanthophyceae and not to the Chlorophyceae. Smith (1950) apparently does not agree with this view, inasmuch as he cites Schiller's study in his description of the genus *Characium*. Filarsky (1926) noted the production and copulation of anisogametes in *Characium saccatum*, but no details as to the zygote and its subsequent development were reported.

The alga that forms the basis for this report was isolated from air-dried soil collected under the direction of Dr. M. A. Pocock from the Cape Flats near Cape Town, South Africa, and sent to the Botany School of Cambridge University, England. Gametic pairs, which appeared in a culture tube, were isolated by means of fine glass pipettes and placed in tubes of soil-water medium (Pringsheim 1946, 1950). Bacteria-free cultures of the two sexual strains were obtained by streaking the surface of an agar plate with motile cells. Two types of media were used in the study of the various phases of the life history: soil-water medium of Pringsheim and soil extract

[1] The larger part of this investigation was completed while the writer was at the Botany School, Cambridge University, as a Fulbright Scholar, in 1950–51.

agar. The latter was made by adding soil extract (Pringsheim 1946) to Bristol's agar (Bold 1949) in the ratio of 1:10. The cultures were illuminated by light from a fluorescent fixture; an intensity of from 50 to 75 footcandles was used for agar cultures, while 100 footcandles gave optimum results in the soil-water cultures. Zoosporogenesis was studied in the living condition in hanging drop preparations and in whole mounts fixed with Schaudinn's fixative and stained with Heidenhain's iron alum haematoxylin.

Observations. The typical vegetative cell of *Characium saccatum* is ovoidal with a rounded apex and a basal portion which is only slightly elongate and narrowed (fig. 1). Young cells tend to be much more elongate than older ones, which are almost spherical. No distinct holdfast organ has been observed. The largest of the vegetative cells vary between 15 and 20 microns in length; the diameter varies with the shape of the cell. The majority of the cells, however, tend to be smaller. The cell wall is thin, nor does it thicken appreciably with age.

Unlike *C. Sieboldii* (Smith 1916) and *C. angustum* (Carter 1919), each cell of *C. saccatum* possesses a chromatophore which is more or less sharply delimited from the remainder of the protoplast. The chromatophore is a laminate, parietal sheet which, in some instances, seems to be almost cup-shaped, the open part of the cup being directed downward toward the base of the cell. It is only immediately before and during cleavage in the formation of zoospores and gametes that the chromatophore becomes indistinct. At this time, the cell contents become finely granulated and the chlorophyll appears diffuse in the cytoplasm; the greater portion of the chlorophyll, however, remains at the periphery of the cell. A single oval to spherical pyrenoid is present in the chromatophore; it is located near the periphery at a point usually intermediate between the base and the apex.

The cells of *Characium saccatum* are uninucleate at maturity (fig. 17). It is only in preparation for cleavage that the nucleus undergoes successive mitotic divisions, thus giving rise to a multinucleate cell (figs. 18, 19).

Zoosporogenesis was initiated by the transfer of cells from agar medium on which they had been growing to fresh agar medium. This proved to be the best way of securing zoospores or gametes in large quantities. The cleavage of the cells is usually completed within 24 to 48 hours after transfer, depending on the metabolic state of the cells transferred.

That a cell is preparing to undergo cleavage is evidenced by the fact that the chromatophore limits become indistinct (figs. 2, 3). The central region of the cell appears as a translucent colorless area in which the successive mitotic divisions of the nucleus occur in preparation for cleavage. The pyrenoid remains as a distinct body in its usual position. Cleavage is of the progressive type, but the process varies in some slight degree among the various cleaving cells. In some cells, a single transverse furrow arises

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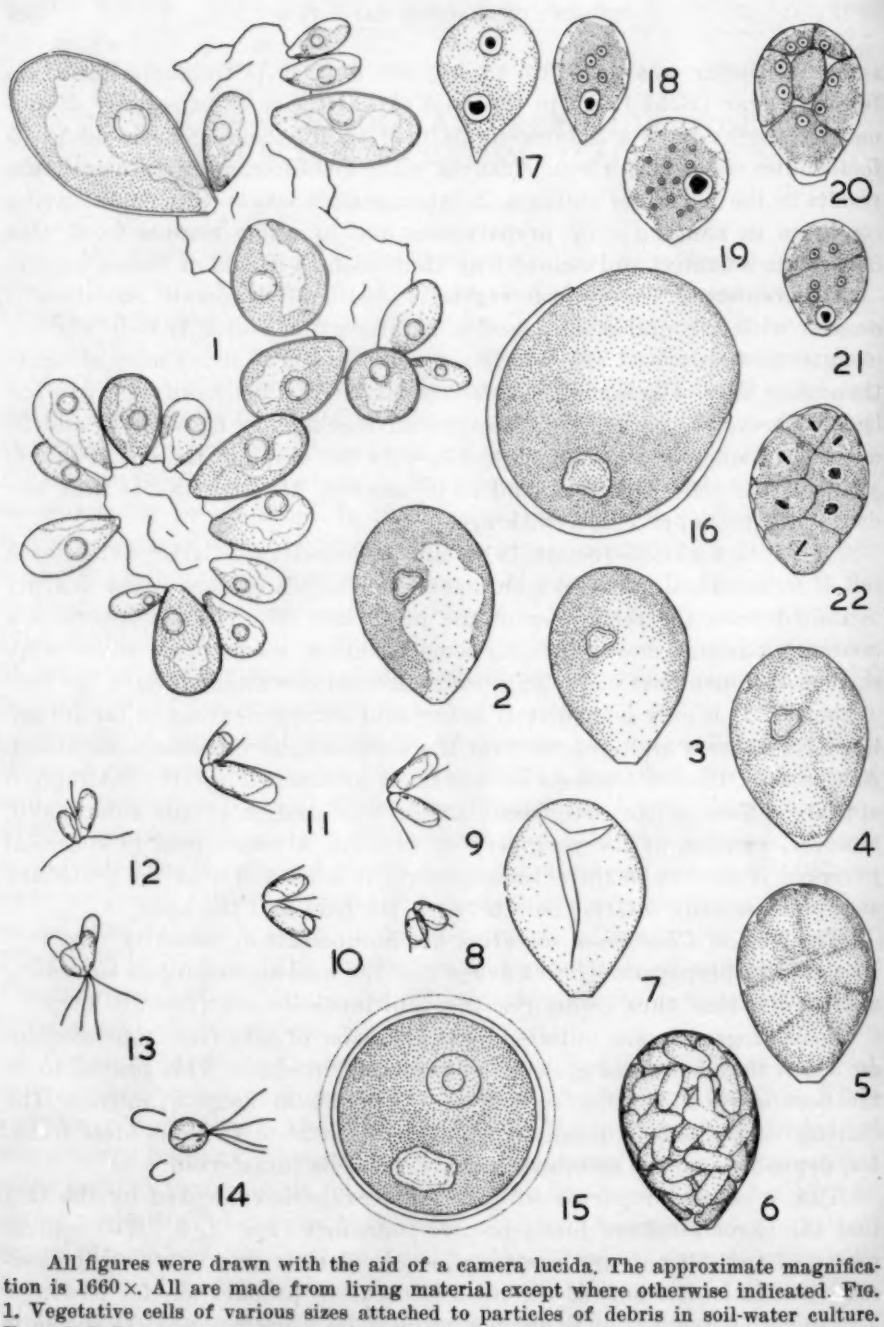

All figures were drawn with the aid of a camera lucida. The approximate magnification is 1660×. All are made from living material except where otherwise indicated. FIG. 1. Vegetative cells of various sizes attached to particles of debris in soil-water culture. FIGS. 2–7. Stages in zoosporogenesis. FIGS. 8, 9. Gametic pairs of equal sized individuals. FIGS. 10, 11. Gametic pairs showing some degree of anisogamy. FIGS. 12–14. Stages in plasmogamy of gametes. FIG. 15. Mature zygospore. FIG. 16. Early stage of zygospore germination. FIG. 17. Mature vegetative cell, stained with iron alum haematoxylin. FIGS. 18, 19. Vegetative cells just preceding cleavage, showing multiplication of the nuclei through successive mitoses, stained with IAH. FIGS. 20, 21. Stained preparations of cleaving cells. FIG. 22. Stained preparation of cleaving cell in which additional mitoses are occurring after cleavage has begun.

first and is followed by a series of centrifugal furrows over the surface of the two parts (fig. 21). In other cells, there appear to be no primary furrows; instead, a series of furrows develops simultaneously over the surface (figs. 4, 5, 20). In the early stages of cleavage the pyrenoid remains as a distinct body which is included in one of the divisions of the protoplast; however, as cleavage progresses, the pyrenoid becomes more and more indistinct and finally loses its identity completely.

Stained specimens often show that mitotic divisions of the nuclei may occur in the segments of the protoplast which have been delimited by the first cleavage furrows (fig. 22). This is very similar to the situation in *Protosiphon* (Bold 1933) in which nuclear divisions occur in the protospores in the last stages of the progressive cleavage.

The uninucleate masses, which are eventually delimited, metamorphose into biflagellate motile cells (fig. 6). Release of these is accomplished by a lateral rupture of the cell wall (fig. 7). If the opportunity for sexual union does not present itself because of the absence of suitable mating types, each motile cell acts as a zoospore, settling down in some surface where it grows into a new vegetative cell. On the other hand, if motile cells from the two heterothallic strains of *C. saccatum* are mixed, there is an immediate sexual reaction in the form of violently whirling and jiggling clumps. From these clumps, pairs of gametes soon emerge and come to rest on the cover glass of the hanging drop preparation, in which they are most easily observed. There is often a pronounced difference in the size of individuals of a gametic pair (fig. 11), but the observation of numbers of pairs with members of equal size (figs. 8, 9, 10) indicates that this is probably a matter of random selection. Examination of the gametes of the two strains shows that in both strains there is a wide variation in the size of motile cells produced; the sizes vary between 4 by 2 microns and 7½ by 3 microns.

Within 15 to 30 minutes after the gametic pairing occurs, union of the gametic protoplasts is initiated. This is accomplished in a matter of seconds, each gamete protoplast slipping out of its very delicate wall and fusing laterally with its partner (figs. 13, 14). The delicate, discarded gametic walls are visible only with careful illumination and at the time of the sexual union; they apparently disintegrate shortly after being discarded. The zygotes remain motile for some time after plasmogamy. They vary in size, depending on the sizes of the uniting gametes which formed them, but the average length is in the vicinity of 4½ microns. Each zygote, which may be spherical or ovoid in shape, possesses two chromatophores, two stigmata and four flagella (fig. 14).

Mature zygotes were obtained by streaking the surface of Bristol's agar or soil extract agar plates with newly formed zygotes. Even though on the plates there were zoospores and vegetative cells in addition to the zygotes,

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the latter could be identified within a week by their darker green color and larger size. After two to three weeks, their color changed to yellowish-green to brownish. Mature zygospores are spherical in shape, and reach a maximum size of 20 microns in diameter (fig. 15). The protoplast is surrounded by a thin smooth cell wall which does not thicken to any extent. A gelatinous layer is often present exterior to the cell wall.

Germination of the zygospores of *C. saccatum* was observed on an agar plate within 10 days after their formation. Approximately 50% of the zygospores remained dormant on the plate. The first indication of germination is the swelling of the cell, accompanied by the rupture of the wall and subsequent protrusion of part of the protoplast (fig. 16). Observations of living zygospores during cleavage suggest that cleavage is of the progressive type; however, this has not been verified by means of stained preparations, inasmuch as germinating zygospores in sufficient quantity have not yet been obtained. Upon germination, each zygospore usually produces either 32 or 64 motile cells. These have not been analysed to see whether the sexes are segregated during the division of the zygote nucleus.

Discussion. With the exception of habitat, the alga here described is similar in most respects to *Characium saccatum* which Filarsky (1914, 1926) found on the legs of *Branchipus*. Although the writer's cultures were isolated from soil, there appears to be little reason for considering the present organism as a species different from *C. saccatum* on the basis of host specificity alone. Possibly the alga was epizooic in its normal habitat.

The fate of the pyrenoid in zoosporogenesis appears to vary in different species of the same genus. In *Characium Sieboldii* (Smith 1916) and in *Characium saccatum*, the pyrenoid remains unchanged during the first stages of cleavage and gradually disappears during the later stages. In *Characium angustum* (Carter 1919), a division of the pyrenoid occurs just previous to each mitotic division and subsequent bipartition of the protoplast. Bold (1931) reports that in *Chlorococcum infusionum* (Schrank) Meneghini the pyrenoid fragments just prior to cleavage, each cleavage segment eventually receiving a fragment; this condition, however, has not been reported for species of *Characium*.

Filarsky's report of anisogametes in *C. saccatum* may be explained, perhaps, by his failure to grow the alga in culture. As pointed out in the description of the sexual process in the writer's alga, the wide divergence of size among gametes produced by each of the sexual strains is responsible for the appearance of many apparently anisogamous pairs. Only through the use of culture methods can it be ascertained that both sexual strains produce gametes of variable sizes; mixed cultures may readily give the impression that the smaller gametes are of one sex and the larger of the other.

SUMMARY

1. The morphology and reproduction of *Characium saccatum* Filarsky are described, based on observations of the organism in unialgal culture.

2. Sexual reproduction is accomplished by the union of heterothallic isogametes. The mature zygospore is spherical and smooth-walled.

3. Asexual reproduction is accomplished by zoospores (facultative gametes) which are produced by a series of progressive cleavages. The pyrenoid of the vegetative cell gradually disappears during cleavage; each zoospore, however, possesses a pyrenoid which apparently arises *de novo*.

4. Bacteria-free cultures of the two heterothallic strains have been placed in the Culture Collection of Algae at the Botany School of Cambridge University, England. Cultures are also maintained by the writer.

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BULLETIN OF THE TORREY BOTANICAL CLUB
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ON THE OCCURRENCE OF GRACILARIOPSIS IN THE ATLANTIC AND CARIBBEAN[1]

E. YALE DAWSON

In a recent treatise on Northeast Pacific Gracilariaceae (Dawson 1949) the writer has shown that along the Pacific Coast of Mexico and the United States there coexist two superficially indistinguishable, but gentically dissimilar plants. These two species are now known as *Gracilaria verrucosa* (Huds.) Papenf. and *Gracilaria sjoestedtii* (Kylin) Dawson, but until recent years collections of either one, or mixtures of the two have been identified as *Gracilaria confervoides* (L.) Grev. Sjoestedt (1926) first noted differences between the two species but did not recognize the full taxonomic significance. Kylin (1930) recognized the cystocarpic differences as specific and described *Gracilaria sjoestedtii* as a new species. The writer has shown (1949) that whereas the genus *Gracilaria*, as typified by *G. verrucosa* (= *G. confervoides*) is characterized, among other things, by the presence of accessory nutritive filaments in the cystocarp, radiating from the gonimoblast to the pericarp and apparently contributing toward nourishment of the developing carpospores. Such special filaments are lacking in a group of plants which he placed under *Gracilariopsis*. Furthermore, it was shown that in both of these genera a variety of types of antheridial sori occur which are highly important in making specific segregations. In *Gracilaria verrucosa*, for example, the antheridia are borne in small, non-confluent pits which are about as broad as deep. In *Gracilariopsis sjoestedtii* the antheridia are borne in continuous superficial sori in which no depression or elevation of the sorus surface is evident, and in which only scattered, pigmented vegetative cells occur. Male plants are, therefore, impossible to recognize by gross examination, and the antheridia must be sought with the aid of thin transections or tangential surface slices.

Along the Pacific Coast of North America *Gracilaria verrucosa* seems to occur as far north as Puget Sound, and *Gracilariopsis sjoestedtii* at least as far north as Coos Bay, Oregon. Along the entire range southward to southern Baja California and throughout the Gulf of California *G. sjoestedtii* appears to be the more abundant species in a ratio of two or three to one.

In examining cystocarps in several sets of collections obtained by the writer in Cuba in May 1949 it became apparent that both *Gracilaria* and *Gracilariopsis* were represented. A thorough search of the material yielded several antheridial plants and conclusively demonstrated the coexistence

[1] Contribution 97 from the Allan Hancock Foundation.

of the same two species in the Cuban region as along Pacific North America. *Gracilaria verrucosa* was represented by a set of plants, including all three reproductive phases, from Bahia Cienfuegos, Las Villas Province, Cuba (Dawson 7656). *Gracilariopsis sjoestedtii* was represented by two sets, each containing all three reproductive phases: Dawson 7714, east side of Bahía Santiago, Oriente Province; Dawson 7738, inner margin of Bahía Matanzas, Matanzas Province. A set of specimens from Tarifa, Camaguay Province (Dawson 7617–7618) has proved by its cystocarps to be *Gracilariopsis*, but its antheridia set it apart as a different species. The antheridia arise from the bottom of closely approximate, small, subspherical, non-confluent, pouch-like pits, somewhat like those in *Gracilaria verrucosa*. The species seems to be one which has been recognized by several authors as *Gracilaria cornea* J. Ag. Should it prove to be that insufficiently known Brazilian species, a transfer will be called for.

Following these interesting observations, other similar material in the Hancock Herbarium from the Caribbean and adjoining Atlantic was examined. Unfortunately, in very few conventional herbarium collections are both cystocarpic and antheridial plants represented together. It is, thus, usually impossible to make specific identification, for neither antheridial nor cystocarpic specimens are alone sufficient. In one instance both were found together in a collection from intertidal rocks in the harbor at Willemstad, Curaçao (Taylor 39–566a). In this plant the antheridia are borne in a completely superficial, reticulate sorus of elongate, anastomosing areas separated by islands of linear or lenticular groups of vegetative cells. This feature is characteristic of *Gracilariopsis costaricensis* Dawson, described from virtually the same latitude and a similar habitat in Pacific Costa Rica. The single collection is not entirely conclusive as to identity, but indicates the occurrence in the strictly tropical south Caribbean of a plant which is closely related, but seemingly distinct from *G. sjoestedtii*.

The occurrence of these and (or) other *Gracilariopsis* species along Atlantic United States is indicated by cystocarpic collections from Fort Fisher, North Carolina by L. G. Williams, from Jupiter Inlet, Florida by the writer, and from Anastasia Island, Florida in Phyc. Bor. Amer. no. 384c. However, antheridial plants have not yet been seen from these or other Atlantic Coast localities and must be had for specific identification.[2]

During this study a considerable number of pertinent plants of European collections have been examined. All of these have proved by their cystocarps to be characteristic of *Gracilaria verrucosa* rather than of species of *Gracilariopsis* which remains unrecorded for the eastern Atlantic.

[2] Since the above was written Dr. Williams has sent material from Fort Fisher, North Carolina, collected in June 1952, which includes all reproductive phases and which agrees completely with Pacific specimens of *Gracilariopsis sjoestedtii*. This record places the species unquestionably in the flora of Atlantic United States.

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It may be pointed out that inasmuch as "*Gracilaria confervoides*" has long been known and used as an agarphyte, that some critical examinations are now called for to determine whether *Gracilaria verrucosa* and the several morphologically similar species of *Gracilariopsis* are of equal commercial value as sources of agar, or whether chemical differences between these plants are appreciable and may have been responsible for misleading analytical results in the past.

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TAXONOMIC NOTES ON THE FAGACEAE OF FORMOSA

HUI-LIN LI[1]

A review of the family Fagaceae on the island of Formosa has been made in anticipation of the preparation of a Flora of Formosa. With the aid of large reference collections from mainland China, Hainan, the Philippines, and Japan, it is found necessary to revise the concepts of many of the species as recorded from Formosa. These notes of taxonomic or nomenclatural significance are herein published in advance of a complete treatment of the family.

Considerable differences occur in the delimitation of generic segregates in this family. For Formosan species, the following genera are recognized by the present writer: *Fagus, Castanea, Castanopsis, Lithocarpus, Pasania, Quercus,* and *Cyclobalanopsis.* Notes concerning the last five of these are herein given. This study was based mainly on the collection of the U. S. National Herbarium, Smithsonian Institution, and the herbarium of the National Taiwan University, Formosa. A few specimens from the herbarium of the Taiwan Forestry Institute are also cited. Selected specimens from there herbaria are cited with the abbreviations (US), (NTU) and (TFI) respectively.

CASTANOPSIS

1. CASTANOPSIS BREVISTELLA HAY. & KANEHIRA EX A. CAMUS, CHAT. MONOG. Cast. et Castanop. 481. *f. 16.* 1929; Kanehira, Formos. Trees rev. ed. 89 *f. 45.* 1936; Nakai in Jour. Jap. Bot. **15**: 259. 1939. *Castanopsis sinsuiensis* Kanehira, Formos. Trees rev. ed. 94. *f. 49.* 1936; Nakai in Jour. Jap. Bot. **15**: 260. 1939. *Syn. nov.* Formosa: Sinsuie, *R. Kanehira 21299,* Dec. 14, 1918 (type of *C. sinuiensis* Kanehira, photo US); Sinsuie, *R. Kanehira 21299,* Dec. 14, 1918 (isotype of *C. brevistella* Hay. & Kanehira, photo US).

Camus published Hayata & Kanehira's herbarium name *C. brevistella* in 1929; an isotype, bearing the herbarium number 21299, is in the Taiwan Forestry Institute. Kanehira subsequently described *C. sinsuiensis,* evidently by oversight, on a specimen of the name collection with the same herbarium number.

2. CASTANOPSIS CARLESII (Hemsl.) HAYATA. *Castanopsis carlesii,* based on *Quercus carlesii* Hemsl., was originally described from Fukien. Later it was also credited to Formosa, but its taxonomic status is rather confusing.

[1] Supported in part by a grant from the American Philosophical Society. I am also indebted to Dr. A. C. Smith of the Smithsonian Institution for his kindness in reading the manuscript.

In Formosa, the same species appears under several other names, the identity of which is clarified below.

In 1908, Hayata first identified a specimen "Monte Morrison, T. Kawakami et U. Mori, Oct. 1906" as *Quercus junghuhnii* sensu Hay. non Miq. This name was incorrectly referred to *Castanopsis acuminatissimus* (Blume) Rehder by Camus (Chat. Monog. Cast. et Castanop. 434), a species of Siam and neighboring regions. This particular specimen was included in Sasaki, Cat. Govern. Herb. (Formos.) 167. 1930 as belonging to "*Shiia longicaduata* (Hay.) Kanehira & Sasaki" = *S. longicaduata* Kudo & Masamune, a synonym of *Castanopsis carlesii* var. *carlesii*.

In 1911, Hayata identified another specimen "Taiko, leg. T. Kawakami et B. Hayata, 1908, Aug. (No. 46)," as *Q. carlesii* Hemsl. but with the remark that it "agrees with the figure above cited [Hemsl. in Hook. Ic. Pl. *t. 2591*], excepting that this plant [of Formosa] has a quite sessile fruit, while the other [of Fukien] has always short stalked one." For this reason Nakai in 1939 separated the Formosan plant as a variety, *sessilis*, from the typical form of *Castanopsis carlesii*.

In 1913, Hayata described a new species, *C. longicaudata*, basing it on "Mt. Daibu, leg. S. Nakai, Dec. 21, 1912," a sterile specimen without fruit. He compared his species with *Quercus cuspidata* Thunb., which is very near *Q. carlesii* = *Castanopsis carlesii*. This species later on appeared under the names *Lithocarpus longicaudata* Hay., *Pasania longicaudata* Hay., *Shiia longicaudata* Kudo & Masamune, and *Castanopsis longicaudata* Nakai; it is actually identical with the typical form of *Castanopsis carlesii* from Fukien, similarly with very short stalks on the cupules.

The sessile form identified earlier by Hayata as *Q. junghuhnii* was apparently also given the name *Q. stipitata* Hay. in the herbarium. Koidzumi took up this name in 1916, proposing a combination *Synaedrys stipitata*, which he later changed to *Lithocarpus stipitata* in 1925. This name was subsequently made into other combinations, such as *Shiia stipitata* Kudo & Masamune and *Castanopsis stipitata* Nakai.

Nakai more properly referred these plants to *Castanopsis* instead of to *Lithocarpus* or to *Shiia*, an unsatisfactory segregate from *Lithocarpus*. However, he, like other authors, recognized *C. stipitata*, *C. longicaudata*, and *C. carlesii* as distinct species and added another variety, *C. carlesii* var. *sessilis*. In his treatment, no specimens are cited. It is believed that all the various combinations made by these Japanese authors are based on literature, without critical review of actual specimens. For this whole assortment of names, only one species with two varieties can be recognized, these pertaining to *Castanopsis carlesii*. In Formosa there is one form with smaller, narrower leaves and short stalked, less spiny fruit, and another with larger, broader leaves, and sessile, more spiny fruits. The former is evidently the

same as the typical form of *C. carlesii* of Fukien, and the latter is here interpreted as a variety.

2a. CASTANOPSIS CARLESII (Hemsl.) HAY. VAR. CARLESII. *Castanopsis carlesii* (Hemsl.) Hay., Gen. Ind. Fl. Formos. 72. 1917; Chun in Jour. Arnold Arb. **8**: 21. 1927; Kudo & Masamune in Ann. Rep. Taihoku Bot. Garden **2**: 12. 1932; Suzuki ex Masamune, Short Fl. Formos. 41. 1936; Nakai in Jour. Jap. Bot. **15**: 257. 1939. *Quercus carlesii* Hemsl. in Hook. Icon. Pl. **26**: *pl. 2591.* 1899. *Quercus longicaudata* Hay. Icon. Pl. Formos. **3**: 182. *f. 29.* 1913, 6: 64. 1916. *Syn. nov. Pasania longicaudata* Hay. Icon. Pl. Formos. **3**: 182. 1913, pro. syn. *Syn. nov. Lithocarpus longicaudata* Hay. Gen. Ind. Fl. Formos. 72. 1916. *Syn nov. Synaedrys carlesii* Koidz. in Bot. Mag. Tokyo **30**: 186. 1916. *Shiia longicaudata* Kodo & Masamune in Jour. Soc. Trop. Agr. **2**: 35. 1930; Kanehira & Sasaki in Sasaki, Cat. Govern. Herb. (Formos.) 167. 1930; Kanehira, Formos. Trees rev. ed. 135. *f. 81.* 1936. *Syn. nov. Shiia carlesii* Kudo in Jour. Soc. Trop. Agr. **3**: 17. 1931. *Syn. nov. Castanopsis longicaudata* Nakai in Jour. Jap. Bot. **15**: 265. 1939; Kanehira & Hatusima in Trans. Nat. Hist. Soc. Formos. **29**: 155. 1939. *Syn. nov. Pasania cuspidata* sensu Matsum. & Hay. in Jour. Coll. Sci. Tokyo **22**: 392. 1906 (Enum. Pl. Formos.), non Oersted. Fukein; Formosa, abundant in forests throughout the island. Formosa: Arisan, *R. Kanehira 2935* (US); Funkiko, prov. Nanto, *E. H. Wilson 10826* (US); Sintiku-syu, Taikogun, *T. Suzuki,* Oct. 6, 1930 (NTU); Rengechi, Taichu, *Kawahara & Hayama,* April 1944 (NTU); Kuskus, Hunchuen, *H. Keng,* 1335 (US); Mt. Daibu, *Nakai* 7458 (isotype of *Q. longicaudata* Hay., photo US).

2b. CASTANOPSIS CARLESII (Hemsl.) HAY. VAR. SESSILIS NAKAI, in Jour. Jap. Bot. **15**: 261. 1939. *Quercus stipitata* Hay. ex Koidz. in Bot. Mag. Tokyo **30**: 187. 1916, pro syn. *Syn. nov. Synaedrys stipitata* Koidz. in loc. cit., nomen. *Syn. nov. Lithocarpus stipitata* Koidz. in Bot. Mag. Tokyo **39**: 2. 1925. *Syn. nov. Shiia stipitata* Kudo & Masamune in Bot. Mag. Tokyo **44**: 406. 1930; Kanehira & Sasaki in Sasaki, Cat. Govern. Herb. (Formos.) 167. 1930; Kanehira, Formos. Trees rev. ed. 135. *f. 82.* 1936. *Syn. nov. Castanopsis stipitata* Nakai in Jour. Jap. Bot. **15**: 206. 1935; Kanehira & Hatusima in Trans. Nat. Hist. Soc. Formos. **29**: 155. 1939. *Syn. nov. Quercus carlesii* sensu Hay. Jour. Coll. Sci. Tokyo **30** (1): 289. 1911 (Mat. Fl. Formos.), non Hemsl. *Quercus junghuhnii* sensu Hay. in Jour. Coll. Sci. Tokyo **25**(19): 203. 1908 (Fl. Mont. Formos.); Kanehira, Formos. Trees 570. 1917; non Miq. Endemic to Formosa; in forests, from 350 to 2500 meters, in northern and central parts of the island. Formosa: Taihoku, *E. H. Wilson 10204* (US); Juykirin, Shinchiku, *E. H. Wilson 10137* (US); Arisan *E. H. Wilson 10890* (US); Horisha, prov. Nanto, *E. H. Wilson 11191* (US); Bunzangun, Taihoku, *T. Nakamura 4774* (NTU).

3. CASTANOPSIS KAWAKAMI HAY. in Jour. Coll. Sci. Tokyo **30** (1): 300. 1911 (Mat. Fl. Formos.); Kanehira, Formos. Trees 551. 1917, rev. ed. 90. *f. 47,* 1936; Camus, Chat. Monog. Cast. et Castanop. 290. *f. 14,* 1929; Suzuki ex Masamune, Short Fl. Formos. 41. 1936. Formosa. Formosa: Funkiko, prov. Kagi, *E. H. Wilson 9637* (US); Hokkokei, Taichu, *T. Tomiya,* March 29, 1944 (NTU).

Handel-Mazzetti (in Beih. Bot. Centralbl. **48**: 295. 1931) and Nakai (in

Jour. Jap. Bot. **15**: 259. 1939) consider this Formosan plant as conspecific with *C. borneensis* King, which is also recorded from Kwangtung and Hainan. Metcalf (Fl. Fukien **1**: 59. 1942), however, suggests that the Hainan plants have much smaller fruit and are different from authentic material from Formosa. Hainan specimens observed by the present writer are noted to have narrower leaves with narrower bases and fewer spines on the fruit and are evidently distinct from the Formosan plants.

LITHOCARPUS

1. LITHOCARPUS AMYGDALIFOLIUS (Skan) HAY. Gen. Ind. Fl. Formos. 72. 1916. *Quercus amygdalifolia* Skan in Forbes & Hemsl. in Jour. Linn. Soc. **26**: 506. 1899. *Pasania amygdalifolia* Schottky in Bot. Jahrb. 47. 660. 1912. *Synaedrys amygdalifolia* Koidz. in Bot. Mag. Tokyo **30**: 188, 1916. Formosa, common in forests of central and southern mountains at altitude of 1500–2500 meters. Formosa: Arisan, *E. H. Wilson 9672* (US), *10891* (US), *T. Tanaka 530* (US) *Y. Yamamoto & T. Nakamura,* Dec. 17, 1939 (NTU); Kuraru, Kosyun, *S. Sasaki,* April 9, 1934 (NTU).

This species was also recorded from Hainan (Tanka & Odashima in Jour. Soc. Trop. Agr. **10**: 363, 1938) and Kwangtung, but specimens from these places differ from those of Formosa in both leaf and fruit characters. Perhaps a different plant is actually represented.

PASANIA

1. PASANIA FORMOSANA (Skan) SCHOTTKY in Bot. Jahrb. **47**: 670. 1912; Nakai in Jour. Jap. Bot. **15**: 272. 1939. *Quercus formosana* Skan ex Forbes & Hemsl. in Jour. Linn. Soc. **26**: 513. 1899. *Synaedrys formosana* Koidz. in Bot. Mag. Tokyo **30**: 195. 1916. *Quercus dodonaeifolia* Hay. Icon. Pl. Formos. **3**: 181. *f. 27.* 1913. (as *dodoniaefolia*). *Lithocarpus dodonaeifolia* Hay. Gen. Ind. Fl. Formos. 72. 1916. (as *dodoniaefolia*). *Synaedrys formosana* var. *dodonaeifolia* Kudo in Jour. Soc. Trop. Agr. **3**: 387. 1931. (as *dodoniaefolia*). *Pasania dudonaeifolia* Hay. Icon. Pl. Formos. **3**: 181. 1913, pro. syn. (as *dodoniaefolia*). Formosa, Hunchuen Peninsula only. Formosa: Sinsuei, *R. Kanehira 21291, 21293* (photo US).

As noted by Sasaki, Cat. Govern. Herb. (Formos.) 162, 1930, but overlooked by most other authors, *Quercus dodonaeifolia* Hay. is a synonym of *Pasania formosana* (Skan) Schottky. *Quercus dodonaeifolia* was originally misspelled as *Q. dodoniaefolia* by Hayata, but was corrected to *dodonaeifolia* by the Index Kewensis; but this was again neglected by other Japanese authors except Nakai.

2. PASANIA GLABRA (Thunb.) OERST. in Kjoeb. Vidensk. Meddel. **18**: 83. 1866. *Quercus glabra* Thunb. Fl. Jap. 175. 1784. *Quercus sieboldiana* Blume, Mus. Bot. Lugd. Bat. **1**: 290. 1850. *Quercus thalassica* Hance in Hook. Jour. Bot. **1**: 176. 1849. *Pasania thalassica* Oerst. in Kjoeb. Vidensk. Meddel. **18**: 83. 1866. *Quercus taitoensis* Hay. in Jour. Coll. Sci. Tokyo **30** (1): 297. 1911 (Mat. Fl. Formos.). *Lithocarpus glabra* Nakai, Catal. Sem. Herb. Bot. Univ. Tokyo 8, 1916; Rehder in Bailey, Stand. Cycl. Hort. **6**: 3569. 1922. *synaedrys glabra* Koidz. in Bot. Mag. Tokyo **30**: 196. 1916. *Synaedrys taitoensis* Koidz. in op. cit. 198. *Lithocarpus taitoensis* Hay. Gen. Ind. Fl. Formos. 72, 1917. *Kuromatea glabra* Kudo in Trans. Nat. Hist. Soc. Formos.

20: 163. 1930. *Pasania sieboldiana* Nakai in Jour. Jap. Bot. **15**: 274. 1939. Formosa: Central Range, *T. Kawakami & N. Mori 2216* (isosyntype of *Q. taitoensis* Hay., photo US).

The Chinese plant, originally described as *Quercus thalassica* Hance, has long been considered by most authors as conspecific with the Japanese plant described as *Quercus glabra* Thunb. Nakai, in Bot. Mag. Tokyo **40**: 581. 1926, & Journ. Jap. Bot. **15**: 275. 1939, considered the Chinese plant as differing specifically from that of Liukiu, Japan, and Formosa in the shape of the fruit. Because of the long and familiar usage of the name *Lithocarpus glabra* for the Chinese plant, he revived Blume's later name for the Japanese plant. As *Quercus glabra* is typified by specimens from Japan only, this is not an acceptable practice. Handel-Mazzetti, Symb. Sin. **7**: 31, 1936, is of the opinion that the Japanese and Chinese plants are conspecific. After re-reviewing many specimens from China and Japan, which show slight and variable changes in the shape and size of the fruits and also in the vegetative characters, I am inclined to agree with Handel-Mazzetti and most modern authors in considering the plants of all these regions as belonging to a single but more or less variable species.

3. **Pasania hypophyaea** (Hay.) comb. nov. *Quercus hypophyaea* Hay. Icon. Pl. Formos. **3**: 182. *f. 28*, 1913; Kanehira, Formos. Trees 569. 1917. *Lithocarpus hypophyaea* Hay. Gen. Ind. Fl. Formos. 72. 1916; Kanehira, Formos. Trees rev. ed. 106. *f. 59*. 1936. *Cyclobalanopsis hypophyaea* Kudo in Jour. Soc. Trop. Agr. **3**: 390. 1931; Suzuki in Masamune, Short Fl. Formos. 41. 1936. *Cyclobalanus hypophyaea* Nakai in Jap. Jour. Bot. **15**: 268. 1939. Formosa, in forests of the eastern side of the Sinsuie Ridge, Hunchuen Peninsula, at altitude of 300–700 meters. Formosa: Sinsuipo, Daibu, Taito, *T. Tomaya 194* (NTU).

This, together with the following species, has cupules partly covering the glans, and thus belonging to *Pasania* rather than *Lithocarpus*, sensu strictu.

4. **Pasania kodaihoensis** (Hay.) comb. nov. *Quercus kodaihoensis* Hay. Icon. Pl. Formos. **4**: 21. t. 4. 1914. *Lithocarpus kodaihoensis* Hay. Gen. Ind. Fl. Formos. 72. 1916; Kanehira, Formos. Trees rev. ed. 109. *f. 60*. 1936. *Synaedrys kodaihoensis* Kudo in Jour. Soc. Trop. Agr. 3. 388, 1931; Suzuki ex Masamune, Short Fl. Formos. 43. 1936; Nakai in Jour. Jap. Bot. **15**: 267. 1939. Formosa, known from southeastern part and Hunchuen Peninsula. Formosa: Daizuurin, Takao, *H. Simizu 3610* (NTU); Taikei, Mt. Mokukua, Karenko, *T. Tomiya*, Oct. 19, 1943 (NTU); Kagi; *S. Nakai 7433* (isotype, photo US).

This species is very close to *P. konishii* (Hay.) Schottky, differing chiefly in the more shallow cupules.

5. Pasania konishii (Hay.) Schottky in Bot. Jahrb. **47**: 673. 1912; Nakai in Jour. Jap. Bot. **15**: 272. 1939. *Lithocarpus konishii* Hay. Gen. Ind. Fl. Formos. 72. 1916; Kanehira, Formos. Trees rev. ed. 109. *f. 60*. 1936. *Quercus cornea* Lour. var. *konishii* Hay. Icon. Pl. Formos. **3**: 179. 1913. *Synaedrys konishii* Koidz. in Bot. Mag. Tokyo **30**: 189. 1916. Formosa; common in the central mountains. Formosa: Lake Candidus, *E. H. Wilson*

9963 (US), *11147* (US); Regenchi, *R. Horiuchi,* Oct. 1931 (NTU), *S. Suzuki,* May 2, 1923 (NTU); Taito, Tokwasan, *N. Konishi* in 1906 (isosyntype, photo US); Nanto, *G. Nakahara,* Feb. 1907 (isosyntype, photo US).

Both *P. konishii* and *P. kodaihoensis* are very close to *P. cornea* (Lour.) Oerst., of the mainland, and may prove to represent varieties of it. Metcalf, Fl. Fukien **1**: 63. 1942, gave *Q. cornea* Lour. var. *konishii* Hay. as a direct synonym of *Lithocarpus cornea* (Lour.) Rehder, with the remark that it probably represents a form of the species. On page 68 of the same work, he listed *L. konishii* Hay. as doubtfully occurring in Hainan, apparently overlooking the fact that the latter is based on *Quercus cornea* Lour. var. *konishii* Hay.

6. PASANIA RANDAIENSIS (Hay.) SCHOTTKY in Bot. Jahrb. **47**. 683. 1912; Nakai in Jour. Jap. Bot. **15**: 273. 1939. *Quercus randaiensis* Hay. in Jour. Coll. Sci. Tokyo **30**(1): 295. 1911 (Mat. Fl. Formos.). *Quercus rhombocarpa* Hay. Icon. Pl. Formos. **3**: 186. *f. 34.* 1913. *Syn. nov. Lithocarpus randaiensis* Hay. Gen. Ind. Fl. Formos. 72. 1916. *Syn. nov. Synaedrys randaiensis* Koidz. in Bot. Mag. Tokyo **30**: 197. 1916. *Lithocarpus suishaensis* Kanehira & Yamamoto in Yamamoto, Suppl. Icon. Pl. Formos. **3**: 11. *f. 4.* 1927. *Syn. nov. Synaedrys rhombocarpa* Kudo in Jour. Soc. Trop. Agr. **3**: 388. 1931; Suzuki in Masamune, Short Fl. Formos. 43. 1936. *Syn. nov. Synaedrys rhombocarpa* f. *suishaensis* Kudo in Jour. Soc. Trop. Agr. **3**: 389; Suzuki in Masamune, Short. Fl. Formos. 43. 1936. *Syn. nov. Pasania suishaensis* Nakai in Jour. Jap. Bot. **15**: 275. 1939. *Syn. nov.* Formosa, in forests in southern and central parts of the island. Formosa: Jitsugettan, *S. Sasaki,* Sept. 1929 (NTU); between Sekiin and Bokkitsu, *Kudo & Sasaki 15277* (NTU); Cho-bo-tai, Basinshan, *H. Keng,* Nov. 3. 1950 (US).

Pasania randaiensis is the oldest name for this species, based on *Quercus randaniensis,* represented by a sterile specimen, (TFI 7473). This proves to be the same as the currently named *Pasania rhombocarpa.* Nakai also keeps *Pasania suishaensis* as distinct, but Kanehira and Kudo refer this to *P. rhombocarpa.* A photograph of one of the paratypes, Suisha, *R. Kanehira,* Oct. 1916 (TFI 7479, photo US), together with the original description and illustrations, shows that the reduction is justifiable.

7. PASANIA URAIANA (Hay.) SCHOTTKY in Bot. Jahrb. **47**: 683. 1912; Nakai in Jour. Jap. Bot. **15**: 275. 1939. *Quercus uraiana* Hay. in Jour. Coll. Sci. Tokyo **30**(1); 299, 1911 (Mat. Fl. Formos.), Icon. Pl. Formos. **3**: 187. 1913. *Lithocarpus uraiana* Hay. Gen. Ind. Fl. Formos. 72. 1916; Kanehira, Formos. Trees rev. ed. 116. *f. 67.* 1936. *Shiia uraiana* Kanehira & Hatusima ex Kanehira, Formos. Trees rev. ed. 116. *f. 67.* 1936. *Castanopsis uraiana* Kanehira & Hatusima in Trans. Nat. Hist. Soc. Formos. **29**: 155. 1939. *Limlia uraiana* Masamune & Hatusima in Acta Bot. Taiwan. **1**: 1. *pl. 1.* 1948. Formosa, in northern and central parts at medium altitudes. Formosa: Urai, Taihoku, *S. Suzuki,* Aug. 7, 1932 (NTU); Kizan, Bunzangun, Taihoku, *S. Sasaki,* March 11, 1934 (NTU); Kangu, Taipeh, *H. Keng,* Oct. 26. 1950 (US).

This is an interesting and distinct tree, which has been used as the basis of a new genus, *Limlia*. Its characters suggest the possibility of its being of hybrid origin.

QUERCUS

1. QUERCUS SEMICARPIFOLIA SMITH SUBSP. GLABRA (Franch.) Hand.-Mazz. Symb. Sin. **7**: 39. 1929. *Quercus semicarpifolia* var. *glabra* Franch. in Jour. de Bot. **13**: 151. 1899, *p. p. Quercus spinosa* David var. *miyabei* Hay. Icon. Pl. Formos. **7**: 37. 1918; Kanehira, Formos. Trees 583. 1917, rev. ed. 131. *f. 76.* 1936; Suzuki in Masamune, Short Fl. Formos. 42. 1936; Camus, Chênes Monog. Quercus **1**: 409. 1938, Atlas **2**: *pl. 235. f. 10–12.* 1936. Western China; Formosa, central ranges at altitudes of 1500–3100 meters. Formosa: Mt. Morrison, *H. H. Bartlett* 6351 (US); Tencyo and Kirai, *S. Suzuki 1867* (NTU).

This is a low tree with crooked trunk and leaves very variable in size and shape. Formerly the Formosan plant was considered as distinct from the plants in western China, but Handel-Mazzetti treats them as of the same subspecies. The Formosan plant, when compared with specimens from western China, is indeed very similar to the latter, and particularly with some specimens from western Hupeh. In both cases, the leaf-margins vary from entire to distinctly spinose-serrate.

CYCLOBALANOPSIS

1. CYCLOBALANOPSIS GLAUCA (Thunb.) OERST. in Kjoeb. Vidensk. Meddel. **18**: 78. 1866; Kudo & Masamune in Ann. Rep. Taihoku Bot. Gard. **2**: 16. 1931; Suzuki in Masamune, Short Fl. Formos. 41. 1936; Camus, Chênes Monog. Quercus **1**: 282. 1838 (as subsp. *euglauca* Canus); Nakai in Jour. Jap. Bot. **15**: 197. 1939. *Quercus glauca* Thunb. Fl. Jap. 175. 1784; Kanehira, Formos. Trees rev. ed. 124. *f. 71.* 1936. *Quercus sasakii* Kanehira in Hay. Icon. Pl. Formos. **6**: 64. 1916, **7**: 37, *t. 10.* 1917; Camus, Chênes Monog. Quercus **1**: 296. 1938. *Cyclobalanopsis sasakii* Kudo & Masamune in Trans. Nat. Hist. Soc. Formos. **20**: 161. 1930; Suzuki in Masamune, Short Fl. Formos. 42. 1936; Nakai in Jour. Jap. Bot. **15**: 202. 1939. Himalaya, China to Japan; Formosa, very common in forests at low altitudes throughout the island, a most important timber tree.

The reduction of *Q. sasakii* is made by Kanehira himself, who says (loc. cit. 1936) that "the glans of *Q. Sasakii* is depressed globose, but it is nothing but of (= a?) young state of the present species." Nakai (loc. cit. 1939), citing no specimens, considers *Cyclobalanopsis sasakii* as distinct from *C. glauca* and both species as occurring in Formosa. This is not corroborated by an actual study of herbarium specimens available to the present writer.

2. CYCLOBALANOPSIS LONGINUX (Hay.) SCHOTTKY in Bot. Jahrb. **47**: 657. 1912; Suzuki in Masamune, Short. Fl. Formos. 41. 1936; Nakai in Jour. Jap. Bot. **15**: 199. 1939. *Quercus longinux* Hay. in Jour. Coll. Sci. Tokyo **30**(1): 292. 1911 (Mat. Fl. Formos.); Kanehira, Formos. Trees rev. ed. 124. *f. 72.* 1936; Camus, Chênes Monog. Quercus **1**: 268. 1938. *Quercus pseudomyrsinaefolia* Hay. in op. cit. 295. *Quercus taichuensis* Hay. in op. cit. 296.

Cyclobalanopsis pseudomyrsinaefolia Schottky in Bot. Jahrb. **47**: 683; Suzuki in Masamune, Short Fl. Formos. 42. 1936. *Cyclobalanopsis kanehirai* Nakai in Jour. Jap. Bot. **15**: 198. 276. 1939. *Syn. nov.* Formosa, common in forests at altitudes of 800–1400 meters throughout the island; an important timber tree. Formosa: Daiguirin, Takao, *H. Simizu 3912* (NTU); Sakahen & Tencyo, *S. Suzuki 1854* (NTU); Siraku & Sikayo, *S. Suzuki 5193* (NTU); Miyama, Tiponzae, *S. Suzuki 10875* (NTU); Kiriyama & Tiponzae, *S. Suzuki 11012* (NTU).

This species is common and widespread in Formosa. As noted by Kanehira, the leaves are very variable. *Cyclobalanopsis kanehirai* Nakai, based on slight variations in leaf-characters, does not show constant differences from the species.

3. CYCLOBALANOPSIS PACHYLOMA (O. Seem). SCHOTTKY in Bot. Jahrb. **47**: 650. 1912; Kudo in Jour. Soc. Trop. Agr. **2**: 148. 1930; Suzuki in Masamune, Short Fl. Formos. 41. 1936; Nakai in Jour. Jap. Bot. **15**: 201. 1939. *Quercus pachyloma* O. Seem. in Bot. Jahrb. **13**. Beibl. 54. 1897; Matsum. & Hay. in Jour. Coll. Sci. Tokyo **22**: 393. 1908 (Enum. Pl. Formos.); Kanehira, Formos. Trees rev. ed. 128. *f. 74.* 1936; Camus, Chênes Monog. Quercus **1**: 233. 1938, Atlas **1**: *pl. 14, f. 1–4.* 1934. *Cyclobalanopsis tomentosicupula* Hay. Icon. Pl. Formos. **3**: 185. 1913; Suzuki in Masamune, Short Fl. Formos. 42. 1936. *Quercus tomentosicupula* Hay. Icon. Pl. Formos. **3**: 185. *f. 33.* 1913; Kanehira, Formos. Trees rev. ed. 132. *f. 79.* 1936; Wilson in Jour. Arnold Arb. **2**: 34. 1920. Camus, Chênes Monog. Quercus **1**: 233. 1938, Atlas **1**: *pl. 14, f. 5–8*, 1934, **2**: *pl. 231, f. 15–17.* 1936. *Quercus pachyloma* var. *tomentosicupula* Metcalf, Fl. Fukien **1**: 76. 1942. *Syn. nov.*

Fukien, Formosa, in forests, central and northern parts. Formosa: *E. H. Wilson 11164* (US); Hirran-zan, *R. Kanehira 7310* (photo US).

Nakai treats *Cyclobalanopsis tomentosicupula* as a straight synonym of *C. pachyloma*. After reviewing specimens from both Fukien and Formosa, I believe this is the best disposition.

4. CYCLOBALANOPSIS STENOPHYLLOIDES (Hay.) KUDO & MASAMUNE in Jour. Soc. Trop. Agr. **2**: 149. 1931; Suzuki in Masamune, Short Fl. Formos. 42. 1936. *Quercus stenophylloides* Hay. Icon. Pl. Formos. **4**: 21. 1914; Kanehira, Formos. Trees rev. ed. 131. *f. 77.* 1936. *Quercus stenophylla* Makino var. *stenophylloides* Camus, Monog. Quercus **1**: 272. 1938, Atlas **2**: *pl. 233.* 1936. Formosa, scattered on the ridges of high mountains at 2200–2660 meters. Formosa: Arisan, *E. H. Wilson 9745* (US); *R. Kanehira & S. Suzuki 21808* (US); Mt. Morrison, *H. H. Bartlett 6301* (US); Onoue, *S. Suzuki 2611* (NTU); Mokkazan, *T. Tomiya,* Oct. 14, 1943 (NTU); Pinanambu & Yonsyo, *S. Suzuki 5108* (NTU).

This species is closely related to *C. glauca* (Thunb.) Oerst., and replaces the latter at higher altitudes. The type of this species is based on a collection cited as "Mt. Arisan, leg. K. Uyematsu, 1912, Sept." Nakai, in Jap. Jour. Bot. **15**: 203–204, 1939, considers this collection at Tokyo as composite, consisting, besides the specimen from Arisan, of another collection from southern Korea which he refers to *C. stenophylla* var. *latifolia.*

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A CONTRIBUTION ON THE FUNGUS FLORA OF GREECE

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The fungi in Greece have been studied by various well-known mycologists. Among them are P. and H. Sydow, Maire and Petrak. Of the investigators in this country, Politis and Sarejannis have studied the fungi more extensively. All the work done in this field by Maire and Politis is comprised in one paper published in 1940, to which are appended the species identified up to that time by Sarejannis.

In the present contribution, the fungi studied are recorded together with comments on morphology. Spore measurements are given for most species, so that they may bring out ecological variations. Occasionally cultural details are included. Fungus species recorded for the first time from Greece are marked with an asterisk, and hosts recorded for the first time are designated with a cross.

The specimens are in the writer's Mycological Herbarium. A number of them have also been deposited at the Herbarium of the Imperial Mycological Institute, Kew, England. All of the later specimens bear the number of that Herbarium. The names of the fungi are used as they are now accepted in the mycological literature. The same pertains with the names of the economic host plants. In the case of native plants, the names are brought into accordance with those used by Hayek in the Prodromus Florae peninsulae Balcanicae.

Most of the fungi in this publication were identified while the author was working at the Imperial Mycological Institute, Kew, England. For the privilege of using the facilities in that Institute, he is indebted to Dr. S. P. Wiltshire. To the authorities there, he wishes to express his appreciation for their generous help and advice.

PERONOSPORALES

CYSTOPUS LÉV.

1. CYSTOPUS CANDIDUS (PERS. EX CHEV.) LEV. VAR. GLOBOSUS O. SAVUL. (Syn. *Albugo candida* (Pers.) Kuntze) on *Capsella bursa-pastoris* (L.) Medic. collected May 1948 at Rouf, Athens. Crit. Fung. Hel. No. 172. Sporangia, spherical to ovoid, 12–24 × 12–21 μ. An interesting feature of this specimen is that the epidermis covering the pustules on the older portions of the stem has tiny, irregular purple-violet pigmented patches. The same species on *Sisymbrium irio* L.† was collected April 26, 1944 at Botaniko, Athens. Crit. Fung. Hel. No. 179.

2. CYSTOPUS PORTULACAE (DC.) KUNTZE on *Portulaca oleracea* L. collected August 4, 1945 at Botaniko, Athens. Crit. Fung. Hel. No. 169.

PLASMOPARA SCHRÖTER

3. PLASMOPARA VITICOLA (BERK. & CURT. EX DE BARY) BERL. & DE TONI on *Vitis vinifera* L. taken October 28, 1948 at Lykovrisi, Attica. Crit. Fung. Hel. No. 175.

BREMIA REGEL

4. BREMIA LACTUCAE REGEL on *Lactuca sativa* L. collected May 15, 1949 at the Market Place, Athens. Crit. Fung. Hel. No. 174. Herb. I. M. I. No. 38345. Oospores have not been seen.

PERONOSPORA CORDA

5. PERONOSPORA LEPTOSPERMA (DE BARY) GÄUMANN* on *Matricaria chamomilla* L. collected May 16, 1946 at Botaniko, Athens. Crit. Fung. Hel. No. 173. Herb. I. M. I. No. 38346.

6. PERONOSPORA PARASITICA (PERS. EX FR.) TUL. on *Capsella bursa-pastoris* (L.) Medic. collected March 7, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 180. Herb I. M. I. No. 38347.

7. PERONOSPORA SISYMBRII-OFFICINALIS GÄUMANN* on *Sisymbrium irio* L. collected April 26, 1944 at Botaniko, Athens. Crit. Fung. Hel. No. 170.

PERISPORIALES

ERYSIPHE HEDW. F.

8. ERYSIPHE CICHORACEARUM DC. EM. SALMON on *Nicotiana tabacum* L. taken September, 1934 at Rodolivos, Serras. Crit. Fung. Hel. No. 212.

9. ERYSIPHE GRAMINIS DC. on *Cynosurus echinatus* L.† collected May 22, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 199. The same species on *Triticum vulgare* A. & G. collected May 13, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 102. The variety *E. graminis hordei* Marchal has been collected May 18, 1940 on *Hordeum murinum* L. at Botaniko, Athens. Crit. Fung. Hel. No. 193. The same variety on *Hordeum vulgare* L. collected May 13, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 191. The conidia on the last specimen measure 27–33 × 9–10.5 μ. Perithecia abundant up to 220 μ in diameter, round to subspherical, dark brown and partly immersed in the mycelium. They are provided with short, simple, brown appendages.

10. ERYSIPHE PISI DC.* on *Pisum sativum* L. taken June 1, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 217. Only conidia have been observed. They are hyaline, elliptical, barrel shaped or sometimes even cylindrical. In size they vary from 24–30 × 12–15 μ. Mean of 10 conidia 30.8 × 13.3 μ.

11. ERYSIPHE TAURICA LÉV.* on *Daucus carota* L. var. *sativa* DC. collected October 2, 1943 at Athens. Crit. Fung. Hel. No. 233. Mycelium persistent, densely compacted, white to pale buff, perithecia more or less immersed in the mycelium, up to 230 μ in diameter.

AGYRIALES

TAPHRINA FRIES

12. TAPHRINA DEFORMANS (BERK.) TUL. on *Prunus amygdalus* Stokes collected September 12, 1934 at Serras. Crit. Fung. Hel. No. 275.

Uredinales

Cerotelium Arth.

13. Cerotelium fici (Cast.) Arth. II on *Ficus carica* L. collected August 6, 1934 at Serras. Crit. Fung. Hel. No. 135. Maire and Politis (1940) refer to this species by the name *Uredo Fici* Cast. occurring in Zakinthos and Leucas. Anagnostopoulos (1939) reports this rust as being abundant at Gythion.

Uromyces Link

14. Uromyces appendiculatus (Pers.) Link II, III on *Phaseolus vulgaris* L. collected September 15, 1934 at the Railway Stn., Serras. Crit. Fung. Hel. No. 28. Another specimen of II, III on the same host collected August 11, 1940 at Bogiati, Attica. Crit. Fung. Hel. No. 27. Herb. I. M. I. No. 38683.

15. Uromyces armeriae (Duby) Lév.* II, III on *Armeria canescens* Host. taken August 26, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 126. Herb. I. M. I. No. 38610.

16. Uromyces fabae (Pers.) de Bary II, III on *Vicia macrocarpa* Bert.† cult. collected June 1, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 30. Herb. I. M. I. No. 37917. Teliospores 30–35 μ long, apex up to about 8 μ.

17. Uromyces heliotropi Snedinski* II, III on *Heliotropium europaeum* L. collected September 15, 1934 at the Railway Stn., Serras. Crit. Fung. Hel. No. 142. Herb. I. M. I. No. 37966. Urediospores globoid to oval 21–26 μ long, wall thin, yellow-brown, moderately echinoid, 2 equatorial pores. Teliospores 20–28 × 17–21 μ, dark cinnamon-brown, wall 2–3 μ, thicker above and with an umbo, pedicel short.

The teliospores are found for the first time after they were described in Russia by Snedinski in Issatschenko Parasit. Pilze des Gouv. Cherson, p. 229, 1896.

18. Uromyces inaequialtus Lasch. II, III on *Silene spinescens* S. & S. taken in May 1943 on Lykabettos, Athens. Crit. Fung. Hel. No. 128. Herb. I. M. I. No. 38638.

19. Uromyces limonii (DC.) Lév. O, I on *Limonium vulgare* L. collected April 11, 1947 by the Lake Koumoundourou, Attica. Crit. Fung. Hel. No. 151. O, I, II, III of the same species on the same host collected June 12, 1949 by the Lake Koumoundourou, Attica. Crit. Fung. Hel. No. 153. Herb. I. M. I. No. 37967. Aeciospores 24–28 μ long. Urediospores globoid to oval, 25–30 μ long, wall about 2.5 μ, 2–3 pores. Teliospores 26–35 μ long, chestnut-brown, apex up to 5 μ, pedicel long.

20. Uromyces pisi (Pers.) Wint.* II, III on *Lathyrus pratensis* L. collected August 13, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 29.

21. Uromyces polygoni (Pers.) Fuck. II, III on *Polygonum aviculare* sensu lato collected July 25, 1944 at Botaniko, Athens. Crit. Fung. Hel. No. 129. Urediospores globose, about 20–25 μ.

22. Uromyces renovatus Syd.* II, III, on *Lupinus hirsutus* L. cult. collected May 29, 1940 at Marathon, Attica. Crit. Fung. Hel. No. 22. Herb. I. M. I. No. 38084. Urediospores 20–23 μ long and about 20 μ wide, pale cinnamon-brown, wall 2–3.5 μ, closely verrucose-echinulate, pores obscure,

about 5. The urediospore wall is thinner than it is stated by Sydow, "Monographia Uredinarum," Vol. II, p. 113, and by Fragoso, "Uredinales," Vol. II, p. 75, both of whom refer to it as being about 3–4 μ. Teliospores dark brown, 20–25 × 15–20 μ, verrucose.

23. UROMYCES STRIATUS SCHROET. II on *Medicago sativa* L. taken September 16, 1934 at the Railway Stn., Serras. Crit. Fung. Hel. No. 19. Herb. I. M. I. No. 38081. Urediospores globoid, about 19–22 μ, pores 3–4 equatorial. Teliospores collected in 1944 did not germinate on March 15, 1945 at 9°–14° C. nor on May 5, 1945 at about 19° C.

24. UROMYCES TRIFOLII (HEDW. F.) LÉV. sensu lato II, III on *Trifolium campestre* Schreb.† collected May 14, 1944 at Amarousion, Athens. Crit. Fung. Hel. No. 25. Herb. I. M. I. No. 37918. Another specimen of II, III on *Trifolium cherleri L.*† collected May 14, 1944 at Amarousion, Athens. Crit. Fung. Hel. No. 24. Another specimen of II, III on *Trifolium scabrum* L. taken May 14, 1944 at Amarousion, Athens. Crit. Fung. Hel. No. 239.

GYMNOSPORANGIUM HEDW. F.

25. GYMNOSPORANGIUM CLAVARIIFORME (PERS.) DC. O, I on *Crataegus heldreichii* Boiss.† collected June 26, 1940 on Parnis, Attica. Crit. Fung. Hel. No. 63. Herb. I. M. I. No. 37853. Aeciospores 23–27 μ, brown, wall 4–5 μ. Peridial cells 75–110 μ long. Another specimen of O, I on *Cydonia oblonga* Mill.† collected June 26, 1943 on Parnis, Attica. Crit. Fung. Hel. No. 56. Herb. I. M. I. No. 38080. Aeciospores, 25–30 μ, brown. III of this species on *Juniperus oxycedrus* L.† collected March 1942 at Botaniko, Athens. Crit. Fung. Hel. No. 146.

26. GYMNOSPORANGIUM JUNIPERINUM (L.) MART. O, I on *Malus pumila* Mill.† collected September 12, 1934 at Serras. Crit. Fung. Hel. No. 42. Aeciospores, 33–45 μ long, brown.

27. GYMNOSPORANGIUM SABINAE (DICKS.) WINT. O, I on *Pyrus communis* L. taken September 12, 1934 at Serras. Crit. Fung. Hel. No. 43. Herb. I. M. I. No. 38078. Aeciospores, 24–33 μ long, wall 3–5 μ, brown. Another specimen of O, I on the same host has been collected September 1940 on Parnis, Attica. Crit. Fung. Hel. No. 44. Aeciospores 24–36 μ long, wall 3–4 μ, brown.

PUCCINIA PERS.

28. PUCCINIA ACARNAE SYD.* II, III on *Picnomon acarna* Cass. collected October 1943 at Attica. Crit. Fung. Hel. No. 10. Herb. I. M. I. No. 37851. Urediospores 25–30 × 23–25 μ, yellow-brown, intermixed with teliospores. Teliospores 37–50 × 25–33 μ, wall 2–3 μ, slightly rough, apical papilla up to 5 μ, cinnamon-brown, slightly constricted at septum, pedicel short or up to 50 μ long. The pedicels are not as persistent as it is stated by Sydow. In Spain, *Puccinia cirsii* Lasch., which has shorter teliospores, is also recorded on the same host.

Approximately 80 per cent of the teliospores produced in 1943 germinated after remaining in a hanging drop for about 70 hours on October 30, 1943 at about 10° C. The basidia produced either basidiospores or germination hyphae. The germ tubes derived from the basidia sometimes branched and sometimes formed a spiral. Occasionally, at their tip a large swelling was produced.

29. PUCCINIA ALLII (DC.) RUD. II, III on *Allium paniculatum* L. var. *pallens* Boiss. collected June 18, 1943 at Botaniko, Athens. Crit. Fung. Hel. 155. Herb. I. M. I. No. 38608. Telia compact, with paraphyses; teliospores up to 65 μ long, mesospores present. Another specimen of II, III on *Allium sativum* L. collected May 1943 at the Market Place, Athens. Crit. Fung. Hel. No. 156.

30. PUCCINIA ANTIRRHINI DIET. & HOLW. II, III on the leaves and stem of *Antirrhinum majus* L. taken July 29, 1941 at Botaniko, Athens. Crit. Fung. Hel. No. 147.

31. PUCCINIA ARENARIAE (SCHUM.) WINT. III on *Stellaria graminea* L.† collected August 29, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 127.

32. PUCCINIA ASPHODELI (DC.) MOUG. I, III *Asphodelus microcarpus* Salzm. & Viv. taken May 8, 1947 on Lykabettos, Athens. Crit. Fung. Hel. No. 157. Herb. I. M. I. No. 37965. Teliospores 50–65 $\mu \times 30$–45 μ, brown, with pale verrucose outer wall. The aecia are not apparent every year. When found, they are abundant and are readily distinguished by their orange-yellow color.

Annually this rust is first seen in its telial stage. The earliest finding of telia is on January 18, 1944 on Lykabettos, Athens. The first appearance of this rust, however, should be considered as taking place in the beginning of January. This month is one of the coldest in Attica and the ground sometimes is covered with snow. The earliest date of finding aecia is March 29, 1947 on Lykabettos, Athens. The delayed appearance of aecia may correspond to the condition obtaining in *Puccinia podophylli* as described by Whetzel, Jackson and Mains (1925).

The mycelium in the tissues of the host contains dark orange colored particles. The young teliospores have colorless cell walls and a colorless fatty substance, which occurs in the form of large rounded bodies. Later it disperses in the cell, while at the same time the wall layers assume a brown color. In the fully grown teliospores the germ pores are well defined on the inner layer of the wall, which has a light chestnut-brown color, while the outer layer, which is somewhat thicker, has a very light brown color. This layer covers the germ pores.

After numerous germination tests of teliospores, over many years, it has been ascertained that few of them germinate at the end of January. Those that germinate produce long germ tubes, which may be divided at the tips into four cells. The basidial cells have not been observed to produce sterigmata and basidiospores at this period. The optimum period for teliospore germination in Attica appears to be from the middle of February to April. The germinating teliospore produces a short hypha, which is divided into four cells. The sterigmata have a broad base and the two terminal ones are produced earlier than the other two. Basidiospores are produced in abundance. A number of teliospores upon germination produce long hyphae without cross walls. By the end of June only a few teliospores germinate.

Those that germinate produce germ tubes. It appears that under low or high temperatures a limited number of germinating teliospores form germ tubes, while the medium temperatures are conducive to the production of basidiospores as well as germ tubes. The teliospores can produce basidiospores in June if they are collected early in the season and kept in the laboratory, so as to escape perhaps the high outdoor temperatures.

The teliospores have not been observed to retain their germination ability and to produce basidiospores at the beginning of the next rust season. The mycelium of *P. asphodeli* is not systemic in *Asphodelus microcarpus* because infected plants kept in pots from one year to the other did not show infection at the following rust season.

33. Puccinia baudysii Picbauer* in Bull. Inst. Jard. Bot. Univ. Belgrad, I, p. 63, 1928. II, III on *Psilurus incurvus* (Gouan) Schinz & Thellung (Syn. *Psilurus aristatus* (L.) Duv. Jouve) collected June 26, 1940 on Parnis, Attica. Crit. Fung. Hel. No. 116. Herb. I. M. I. No. 38796. Urediospores globoid to oval, 21–22.5 × 19.5–21 μ, wall about 1.5 μ, pale brown, finely echinulate, pores several, scattered. Teliospores 39–61.5 × 16–20 μ, apex 5–7 μ (mostly 4 μ), wall pale brown, cinnamon-brown above. Mesospores present. The telia are surrounded by dark stromatic tissue.

34. Puccinia bromina Erikss. II, III on *Bromus sterilis* L.† collected June 9, 1946 on Parnis, Attica. Crit. Fung. Hel. No. 113. Teliospores 35–45 × 15–20 μ, apex 3–6 μ, wall cinnamon-brown, paraphyses present.

35. Puccinia bupleuri Rud. II, III on *Bupleurum semidiaphanum* Boiss. collected July 24, 1948 at Drosia, Athens. Crit. Fung. Hel. No. 150.

36. Puccinia cardui-pycnocephali Syd. II, III on *Carduus pycnocephalus* L. taken May 15, 1944 at Rouf, Athens. Crit. Fung. Hel. No. 1. Herb. I. M. I. No. 38086. Urediospores subglobose 23–27 μ long, wall about 2 μ, closely and finely echinulate, pale cinnamon-brown. Teliospores 34–40 × 22–26 μ, wall thin, slightly rough above.

37. Puccinia cirsii Lasch. II, III on *Cirsium vulgare* (Savi) Ten. (Syn. *C. lanceolatum*) collected August 28, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 8. Urediospores 26–30 μ long, wall 1.5–2 μ, moderately echinulate. Teliospores 35–40 μ long, wall thin including apex, faintly verrucose.

38. Puccinia coronata Corda II, III on *Avena barbata* Brot.† collected July 6, 1948 at Rouf, Athens. Crit. Fung. Hel. No. 247. Telia on the sheath and blade of leaves, and on the culms, covered. Teliospores sometimes have protuberances also on the sides.

39. Puccinia dispersa Erikss. & Henn. II, III on *Secale cereale* L. collected May 18, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 99.

40. Puccinia eryngii DC. II, III on *Eryngium campestre* L. collected October 1943 in Attica. Crit. Fung. Hel. No. 149. Herb. I. M. I. No. 37963. The teliospores have been tried for germination but they have not been observed to germinate in the season in which they were produced or at the beginning of the next.

41. Puccinia fragosoi Bubák. (Syn. *P. koeleriae* Politis, 1940 non Arth., 1909.) II, III on *Koeleria phleoides* (Vill.) Pers cult. taken May 9, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 109. Herb. I. M. I. No. 37915.

Uredia epiphyllous, small, erumpent by a slit, urediospores 25–30 ×

19–23 μ, wall yellowish, 1–2 μ finely and closely echinulate, pores about 8, scattered.

Telia hypophyllous, black, small, or confluent, long covered, surrounded by paraphyses, teliospores 40–65 × 18–27 μ, angular, more or less constricted, lateral wall thin, at the apex up to 7 μ and often somewhat coronate, chestnut-brown above; sometimes 3 or 4 celled. Few mesospores are present.

The species *Puccinia koeleriae* Arth. was described in Mycologia 1: p. 247, 1909 as the result of an inoculation with telia from *Koeleria cristata* (L.) Pers. which produced aecia on *Mahonia aquifolium* Nutt. Mains (1933) using telia of *P. koeleriae* from *Koeleria cristata* produced abundant pycnia and aecia on *Berberis fendleri* Gray. He also used the resultant aeciospores to infect various grasses, among which he found that *Koeleria cristata* and *Trisetum sesquiflorum* were very susceptible, producing well developed uredia and later telia. He also used naturally produced aeciospores on *Berberis fendleri* to infect *Koeleria cristata* and got an abundant infection.

In Greece *Koeleria phleoides* is annually infected but it has not been ascertained whether *Berberis cretica*, the only indigenous species of the genus, is the alternate host. There are no wild growing species of *Mahonia*.

The earliest finding of uredia of this rust in Attica is January 30, 1943. A small percentage of the urediospores germinated producing very long tubes. Germination tests of teliospores were made after keeping material with telia on the surface of the ground or in the laboratory from one rust season to the other. Teliospores from such material have not germinated before or at the beginning of the next rust season.

42. Puccinia glumarum (Schm.) Erikss. & Henn. II on *Aegilops crassa* Boiss.† cult. collected May 9, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 88. Another specimen of II, III on *Aegilops cylindrica* Host.† cult. collected May 22, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 87. Another specimen of II, III on *Triticum vulgare* A. & G. collected May 13, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 107.

43. Puccinia graminis Pers. II, III on *Avena barbata* Brot.† collected July 6, 1948 at Rouf, Athens. Crit. Fung. Hel. No. 94. Another specimen of II, III on *Hordeum bulbosum* L.† collected June 26, 1949 on Parnis, Attica. Crit. Fung. Hel. No. 118. In a few teliospores the middle wall instead of being horizontal has been observed to have various oblique positions. Another specimen of II on *Lolium rigidum* Gaud. var. *compressum* Boiss.† collected June 26, 1940 on Parnis, Attica. Crit. Fung. Hel. No. 246. Another specimen of II on *Secale cereale* L. collected May 25, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 98. Another specimen of II, III on *Triticum vulgare* A. & G. collected June 25, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 106.

O, I on *Berberis cretica* L. taken June 26, 1940 on Parnis, Attica. Crit. Fung. Hel. No. 148. Herb. I. M. I. No. 37964.

44. Puccinia helianthi Schw.* II, III on *Helianthus annuus* L. collected September 16, 1934 at the Railway Stn., Serras. Crit. Fung. Hel. No. 9.

45. PUCCINIA HORDEI OTTH. (Syn. *P. anomala* Rostr., *P. simplex* (Koern.) Erikss. & Henn.) II, III on *Hordeum vulgare* L. collected May 13, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 95. Herb. I. M. I. No. 37908. Teliospores 40–57 μ long; mesospores present.

46. PUCCINIA HORDEI-MURINI BUCHW.* in Ann. Myc. Vol. XLI, 306–316, 1943. II, III on *Hordeum murinum* L. collected April 17, 1943 at Botaniko, Athens. Crit. Fung. Hel. No. 96. *Hordium* is parasitized by the following rusts: *Puccinia graminis* Pers., *P. glumarum* (Schm.) Erikss. & Henn., *P. hordei* Otth., and *P. hordei-murini* Buchw. According to Buchwald (1943) the germ pores of the urediospores of *P. hordei* generally are 8–9, while in *P. hordei-murini* they are 10–12. The number of mesospores in *P. hordei* on the average is 80 per cent and it is never below 50 per cent; in *P. hordei-murini* it is about 28 per cent and never or seldom goes over 40 per cent. The collected specimen has about 25 per cent mesospores.

The urediospores of this rust differ from those of *P. hordei* in that they are smaller, angular, and their oily content has a deeper orange color. The difference in the color can be observed only in mature and fresh urediospores, as the carotinoid in the oily substance gradually fades out through the action of light.

The earliest finding of uredia is on April 8, 1945 at Rouf, Athens. On May 6, 1945 the first telia were observed. Repeated tests have been made to ascertain the period at which the germination of teliospores takes place. They did not germinate during the season in which they were produced or in the beginning of the next.

47. PUCCINIA LAGURI JAAP. in Ann. Myc. Vol. 14, p. 23, 1916. II, III on *Lagurus ovatus* L. taken May 14, 1944 at Amarousion, Athens. Crit. Fung. Hel. No. 117. Herb. I. M. I. No. 37916. Urediospores oval, 25–30 μ long, wall 1.5–2 μ, pale. Teliospores 45–65 $\times$ 20–25 μ slightly constricted, apex up to 10 μ, chestnut-brown.

48. PUCCINIA LOLIINA SYD.* in Ann. Myc. Vol. 19, p. 247, 1921. II on *Lolium rigidum* Guad. var. *compressum* Boiss. collected on Parnis, Attica, June 26, 1940. Crit. Fung. Hel. No. 80. Another specimen of II, III on *Lolium temulentum* L. cult. collected at Botaniko, Athens, May 22, 1940. Crit. Fung. Hel. No. 85. Herb. I. M. I. No. 37914.

Uredia epiphyllous, small, not in conspicuous lines, erumpent by a longitudinal break; urediospores globose to oval, 19–26 $\times$ 18–20, wall 1.5–2.5 μ, pale yellow. It is interesting to note that Sydow in his description mentions the wall as being 1.5 μ.

Telia hypophyllous, small, often confluent, remaining covered by the epidermis, black; teliospores 40–75 $\times$ 16–25 μ, lower cell often the longer, wall 1–2 μ, up to 10 μ at the apex and darker above, pedicel short. The teliospores become longer and more thickened above than given in the original description. Mesospores present. Another specimen of II, III on *Lolium temulentum* L. var. *arvense* (With.) Bab. cult. taken at Botaniko, Athens, May 22, 1940. Crit. Fung. Hel. No. 84. Herb. I. M. I. No. 37910.

49. PUCCINIA MALVACEARUM MONT. III on *Althea pallida* (Wald. & Kit.) Nym.† Collected August 16, 1944 in Attica. Crit. Fungi. Hel. No. 143. Another specimen of III on *Lavatera arborea* L.† collected May 25, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 145. Another specimen of III on *Malva sylvestris* L. collected March 19, 1950 at Menidi, Attica. Crit. Fung. Hel. No. 272.

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In Attica the individuals of *Malva* spp. dry up during the summer. The only locations where they continue to exist are in watered gardens and along irrigation ditches. The earliest finding of telia is on November 11, 1944. The first pustules are almost always produced on the under side of the leaf blades, scattered or in groups at the margin of the blade. The orange-yellow area around the pustules is primarily due to the mycelium, the cells of which have colored particles. It is interesting that the cells of the young teliospores contain large colorless particles, which become dispersed as the teliospores mature. A 3-celled teliospore was observed with the cells in a row.

Teliospores germinate as soon as they are formed. In January they germinate very well at 6° C. Upon germination they produce either basidiospores or each cell of the basidium produces a thin germination hypha. Sometimes the basidial cells, and especially the terminal ones, round up and become detached before they germinate to produce a hypha. Teliospores produced from November to May do not germinate in June or at any time later.

50. PUCCINIA MENTHAE PERS. II on *Calamintha incana* S. & S.† collected June 1945 in Attica. Crit. Fung. Hel. No. 35. Herb. I. M. I. No. 38609. Another specimen of I, II on *Clinopodium vulgare* L.† collected August 12, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 32. Herb. I. M. I. No. 38613. Another specimen of II, III on *Mentha longifolia* L. collected August 20, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 33.

51. PUCCINIA POARUM NIELS II on *Poa nemoralis* L.† collected October 13, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 124. Uredia with capitate paraphyses.

52. PUCCINIA PODOSPERMI DC. II, III on *Podospermum canum* C. A. M. collected May 19, 1946 on Parnis, Attica. Crit. Fung. Hel. No. 2. Herb. I. M. I. No. 38611. A specimen of O, I, II, III of this species on the same host collected on the same date and at the same place. Crit. Fung. Hel. No. 3. Herb. I. M. I. No. 38612.

53. PUCCINIA PRUNI-SPINOSAE PERS. (Syn. *Tranzschelia punctata* (Pers.) Arth.) The pycnia and aecia of this rust are produced on *Hepatica, Thalictrum* and *Anemone* while the uredia and telia are produced on the almond, apricot, cherry, peach and plum. Three of the alternative hosts have been collected with the infection. II, III on *Prunus amygdalus* Stokes collected August 30, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 38. II, III on *Prunus domestica* L. taken September 15, 1934 at the Railway Stn., Serras. Crit. Fung. Hel. No. 36. II on *Prunus persica* (L.) Batsch† collected July 31, 1940 at Bogiati, Attica. Crit. Fung. Hel. No. 37.

54. PUCCINIA PULVERULENTA GREV. II, III on *Epilobium roseum* Schreb.† collected August 21, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 141. Herb. I. M. I. No. 37962.

55. PUCCINIA RUBIGO-VERA sensu lato II, III on *Haynaldia villosa* (L.) Schur. collected May 29, 1940 at Marathon, Attica. Crit. Fung. Hel. No. 112. Herb. I. M. I. No. 38797.

56. PUCCINIA SCILLAE-RUBRAE CRUCH.* II, III on *Festuca* sp. taken October 14, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 125. Herb. I. M. I. No. 38795. The telia are indehiscent but lack paraphyses and the teliospores have longitudinal ridges. This species is not greatly different from *P. festucinae* Syd.

57. Puccinia sorghi Schw. (Syn. *P. maydis* Béreng.) II, III on *Zea mays* L. collected December 8, 1943 at Botaniko, Athens. Crit. Fung. Hel. No. 115.

58. Puccinia suaveolens (Pers.) Rostr.* Secondary II and III on *Cirsium arvense* (L.) Scop. collected August 18, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 14.

59. Puccinia triticina Erikss. II, III on *Aegilops caudata* L.† taken May 29, 1940 at Marathon, Attica. Crit. Fung. Hel. No. 92. Herb. I. M. I. No. 37912. Urediospores globoid to oval, 20–27 μ long, wall about 1 μ, yellowish-brown. Teliospores 40–60 × 15–25 μ. Another specimen of II, III on *Aegilops crassa* Boiss.† cult. collected May 22, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 90. Another specimen of II, III on *Triticum vulgare* A. & G. collected June 1948 at Botaniko, Athens. Crit. Fung. Hel. No. 277.

60. Puccinia violae DC. II on *Viola* sp. collected August 15, 1943 on Pendeli, Attica. Crit. Fung. Hel. No. 134. Urediospores globoid to oval, 20–28 μ long, pores 2.

Phragmidium Link

61. Phragmidium fragariastri (DC.) Schroet. II, III on *Potentilla micrantha* Ram. collected August 21, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 58. Herb. I. M. I. No. 38085. Teliospores 3–4(5) celled, 50–60 μ long.

62. Phragmidium potentillae (Pers.) Karst II, III on *Potentilla argentea* L.† collected August 12, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 65. Herb. I. M. I. No. 37852. Teliospores 2–4 (mostly 3) septate, slightly or not constricted at septa, 45–80 × 24–28 μ, smooth, small apical papilla, pedicel long, narrow; 2 germ pores per cell.

63. Phragmidium tuberculatum J. Müll. O, I, II on *Rosa micrantha* Sm.† collected June 26, 1940 on Parnis, Attica. Crit. Fung. Hel. No. 61. Pycnia subcuticular, on the upper surface and sometimes on the lower. Aecia caeomatous, with clavate, curved paraphyses, surrounded by dried area. Aeciospores spherical to ellipsoid 24–34.5 × 19.5–21 μ, wall 3 μ, warty. Uredia with curved paraphyses, narrower than those of aecia, not surrounded by dried area. Urediospores, clavate-ellipsoidal with 6–7 scattered pores. A specimen of II, III on the same host has been collected October 10, 1942 on Parnis, Attica. Crit. Fung. Hel. No. 60. Herb. I. M. I. No. 37850. Teliospores 3–5 septate 50–85 × 30–35 μ, apical papilla 12–17 μ, chestnut-brown, very rough, papilla pale and more or less rough.

64. Phragmidium violaceum (Schultz) Wint. II, III on *Rubus ulmifolius* Schott. subsp. *anatolicus Focke* taken September 12, 1934 at Serras. Crit. Fung. Hel. No. 59. Herb. I. M. I. No. 37854. Urediospores 23–26 μ long, wall pale, 2.5–3.5 μ, moderately aculeate-verrucose, paraphysate. Teliospores 3-(a few 2 or 4) septate, 70–90 × 30–35 μ, dark brown, moderately rough, with paler apical papilla; pedicel swollen below.

Coleosporium Lév.

65. Coleosporium inulae Rabenh. II on *Inula attica* Hal. collected October 1943 on Lykabettos, Athens. Crit. Fung. Hel. No. 16. Herb. I. M. I. No. 38077.

Melampsora Cast.

66. Melampsora euphorbiae (Schub.) Cast. I, II, III on *Euphorbia*

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cyparissias L.† collected September 5, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 139. Aeciospores globoid to ovoid or ellipsoid, 22–24 × 18–21 μ. The paraphyses associated with the aeciospores have a capitulum with a diameter of 22.5–30 μ. Urediospores mostly globoid, 17–19 × 15–17 μ.

67. MELAMPSORA HELIOSCOPIAE (PERS.) WINT. II, III on *Euphorbia helioscopia* L. collected May 5, 1945 at Rouf, Athens. Crit. Fung. Hel. No. 138.

68. MELAMPSORA MAGNUSIANA G. WAGNER II, III on *Populus nigra* L.† taken September 15, 1934 at the Railway Stn., Serras. Crit. Fung. Hel. No. 136.

THECOPSORA MAGN.

69. THECOPSORA VACCINIORUM (DC.) KARST. II on *Vaccinium myrtillus* L. collected August 21, 1934 on Ailia, Serras. Crit. Fung. Hel. No. 133. The genus is reported for the first time from Greece.

USTILAGINALES

USTILAGO (PERS.) ROUSSEL

70. USTILAGO AVENAE (PERS.) JENS. on *Avena byzantina* C. Koch† collected May 28, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 72. The same species on *Avena sativa* L. collected May 21, 1948 at Rouf, Athens. Crit. Fung. Hel. No. 73. Herb. I. M. I. No. 37866.

71. USTILAGO BULLATA BERK. (Syn. *U. bromivora* (Tul.) Fish. von Waldh.) on *Bromus sterilis* L. cult. collected May 24, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 79. Herb. I. M. I. No. 38639.

72. USTILAGO CYNODONTIS P. HENN. on *Cynodon dactylon* Pers. collected August 15, 1934 at Serras. Crit. Fung. Hel. No. 66. Herb. I. M. I. No. 37861. The same species on the same host collected September 23, 1944 on Hymettos, Attica. Crit. Fung. Hel. No. 67.

73. USTILAGO MAYDIS (DC.) CORDA on *Zea mays* L. collected September 12, 1934 at Serras. Crit. Fung. Hel. No. 78. Herb. I. M. I. No. 37862.

74. USTILAGO TRITICI (PERS.) ROSTR. on *Triticum vulgare* A. & G. taken May 29, 1940 at Marathon, Attica. Crit. Fung. Hel. No. 71. Herb. I. M. I. No. 37863.

SPHACELOTHECA DE BARY

75. SPHACELOTHECA SCHWEINFURTHIANA (THÜM.) SACC. on *Imperata cylindrica* (L.) Pal. Beauv. collected July 11, 1943 at Lykovrisi, Athens. Crit. Fung. Hel. No. 68. Herb. I. M. I. No. 37867.

76. SPHACELOTHECA SORGHI (LINK) CLINT.* on *Sorghum* sp. collected July 7, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 77. Herb. I. M. I. No. 37860.

PHOMALES

MACROPHOMINA PETR.

77. MACROPHOMINA PHASEOLI (MAUBL.) ASHBY (Syn. *Rhizoctonia bataticola* (Taub.) Butler.) on the roots of *Lycopersicon esculentum* Mill.† collected October 20, 1943 at Botaniko, Athens. Crit. Fung. Hel. No. 166. Maire and Politis (1940) report this fungus on fifteen other hosts.

In sections of the root 15 μ in thickness, mycelium and sclerotia can be

seen in the vessels, however the sclerotia are found mostly on the surface of the roots.

It is interesting that it has been possible to cultivate this fungus on culture media after it has remained six years as a dried herbarium specimen. After 48 hours incubation at 25° C. the diameter of the colony in malt agar was 5.8 cm. and in Dox agar 3.8 cm. Sclerotia formed on the surface of the medium are larger and more abundant in comparison with those formed in the medium. In potato dextrose agar they attain a diameter of 150 μ. The cell walls of the interior cells of the sclerotium are uniformly brown while those of the exterior cells are darker. Later the interior and exterior cell walls become correspondingly darker in color. In parts of the Petri dish where the medium is thin, the sclerotia sometimes are formed in a row along a single hypha. Sometimes two or three sclerotia unite.

The main hyphae are up to 11 μ in diameter. On malt agar there is a superficial growth of a buff-colored mycelium, which has the basal septum of a lateral branch close to its point of origin.

The same fungus has been collected August 10, 1940 on *Glycine max* Merrill at Botaniko, Athens. Crit. Fung. Hel. No. 167. The sclerotia occur in the vessels and in the pith of the lower part of the stem. Sclerotia taken from the pith are spherical to ellipsoid, 60–165 × 57–114 μ. Mean of ten sclerotia 101.7 × 86.4.

In another specimen of the same host, taken on the same date and at the same place, Crit. Fung. Hel. No. 168, the sclerotia from the pith measure 36–99 × 36–81 μ with the mean of ten sclerotia 63.6 × 58.8 μ.

SEPTORIA FRIES

78. SEPTORIA APII-GRAVEOLENTIS DOROGIN* on *Apium graveolens* L. var. *dulce* DC. collected July 31, 1940 at Bogiati, Attica. Crit. Fung. Hel. No. 254. Spores flexuous, 26–38 × 1.5 μ. Mean for length of ten spores, 34.5 μ.

79. SEPTORIA NODORUM BERK.* on *Triticum vulgare* A. & G. taken June 26, 1940 on Parnis, Attica. Crit. Fung. Hel. No. 159. Spores 15–25 × 2–2.5 μ and septate.

MONILIALES

ASPERGILLUS (MICHEL) LINK

80. ASPERGILLUS OCHRACEUS WILH.* on *Lycopersicon esculentum* Mill. collected September 15, 1949 at Rouf, Athens. Crit. Fung. Hel. No. 237.

Oidium Link em. Sacc.

81. OIDIUM EVONYMI-JAPONICAE (ARC.) SACC. on *Evonymus japonica* Thunb. collected October 1934 at Athens. Crit. Fung. Hel. No. 200. According to Salmon (1905) this fungus occurs abundantly in Japan on wild as well as on cultivated bushes but also there perithecia are not produced.

82. OIDIUM ABELMOSCHI THÜM. on *Hibiscus esculentus* L. taken Sep-

tember 5, 1943 at Agia Paraskevi, Athens. Crit. Fung. Hel. No. 204. Blumer (1933) places this in a list of species that do not produce perithecia.

Penicillium LINK

83. PENICILLIUM CHRYSOGENUM THOM* on *Capsicum annuum* L. collected September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 243.

84. PENICILLIUM CITRINUM THOM* on *Solanum melongena* L. collected September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 241.

85. PENICILLIUM DIGITATUM (P.) SACC. on *Citrus aurantium* Risso. collected April 22, 1950 at the Market Place, Athens. Crit. Fung. Hel. No. 274.

86. PENICILLIUM ITALICUM WEHMER on *Citrus aurantium* Risso. collected April 22, 1950 at the Market Place, Athens. Crit. Fung. Hel. No. 273.

87. PENICILLIUM MELEAGRINUM BIOURGE* on *Lycopersicon esculentum* Mill. taken September 15, 1949 at Rouf, Athens. Crit. Fung. Hel. No. 245.

88. PENICILLIUM STOLONIFERUM THOM* on *Solanum melongena* L. collected September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 242.

89. PENICILLIUM URTICAE BAINIER* on *Capsicum annuum* L. collected September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 244.

TRICHODERMA PERS.

90. TRICHODERMA VIRIDE PERS. EX FR. (Syn. *Trichoderma lignorum* (Tode) Harz) on a board of *Pinus* sp. collected June 1949 at Athens. Crit. Fung. Hel. No. 267. This species is the conidial stage of *Hypocrea rufa* (Pers.) Fr. Bisby (1939) has observed that a single ascospore culture of *Hypocrea rufa* produced conidia as described also for *Trichoderma koningi* Oudem., *T. narcissi* Tochinai & Shimada and *T. nunbergii* Szilvinyi. The same author has obtained *T. viride* from ascospores of a specimen determined as *Hypocrea gelatinosa* (Tode ex Fr.) Fr. and suggests that *H. gelatinosa* is only mature *H. rufa.*

CLADOSPORIUM LINK

91. CLADOSPORIUM HERBARUM (PERS.) LINK EX FR. on *Solanum melongena* L. collected September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 252. The isolated strain agrees more specifically with the microspecies *C. elatum* (Harz.) Nannf. The same species on *Pistacia vera* L. collected September 28, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 257. Herb. I. M. I. No. 38971.

ALTERNARIA NEES

92. ALTERNARIA CICHORII NATTRASS* in A First List of Cyprus Fungi, p. 29, 1937, on *Cichorium intybus* L. collected March 31, 1940 at Amarousion, Athens. Crit. Fung. Hel. No. 258. Lesions on leaves, circular, with ill-defined margins, up to 7 mm. in diameter, with a light center and brown or purplish margin. Total length of conidia 96–222 μ, width 12–15 μ. Mean of total length and width of ten conidia 146.1×13.2 μ. Vertical or oblique septa 0–2.

93. ALTERNARIA RAPHANI GROVES & SKOLKO* in Canad. J. Res., Sect. C, XXII, p. 227, 1944. on *Brassica oleracea* var. *capitata* collected August 11, 1940 at Bogiati, Attica. Crit. Fung. Hel. No. 160.

According to Wiltshire (1947) this species seems to be close to *A. brassicae* (Berk.) Sacc., from which it differs in the formation of chlamydospores in nutrient media and the shorter beak.

94. ALTERNARIA TENUIS AUCT. on *Capsicum annuum* L. taken September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 264. Conidia (spore body) 10.5–36 × 8–19 μ, septa very irregularly disposed, more or less constricted at septa and especially at the middle septum, coarsely verrucose, with short beaks, in chains of up to 4 spores borne terminally or laterally on side branches of conidiophores. Conidia may bear up to 4 conidiophores.

The same species on *Lycopersicon esculentum* Mill. collected September 15, 1949 at Rouf, Athens. Crit. Fung. Hel. No. 265. Conidia (spore body) 9–46.5 × 8–12 μ, transverse septa 0–7, longitudinal septa 0–3, usually 1, more or less constricted at septa, slightly verrucose or smooth, in chains of up to 5 spores. The beak is sometimes prolonged to an isthmus up to 34 μ and may have up to 4 septa.

The same species again on *Lycopersicon esculentum* Mill. collected September 15, 1949 at Rouf, Athens. Crit. Fung. Hel. No. 263. Conidia (spore body) 6–27 × 4.5–10 μ, cross septa 0–3, longitudinal septa 0–2, slightly constricted at septa, verrucose sometimes only minutely, catenulate in chains of up to 8, with short beaks. Occasionally the beak is prolonged into a conidiophore having up to 4 septa.

95. *Alternaria tenuissima* (Fr.) Wilt.* on *Pistacia vera* L. taken September 28, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 262.

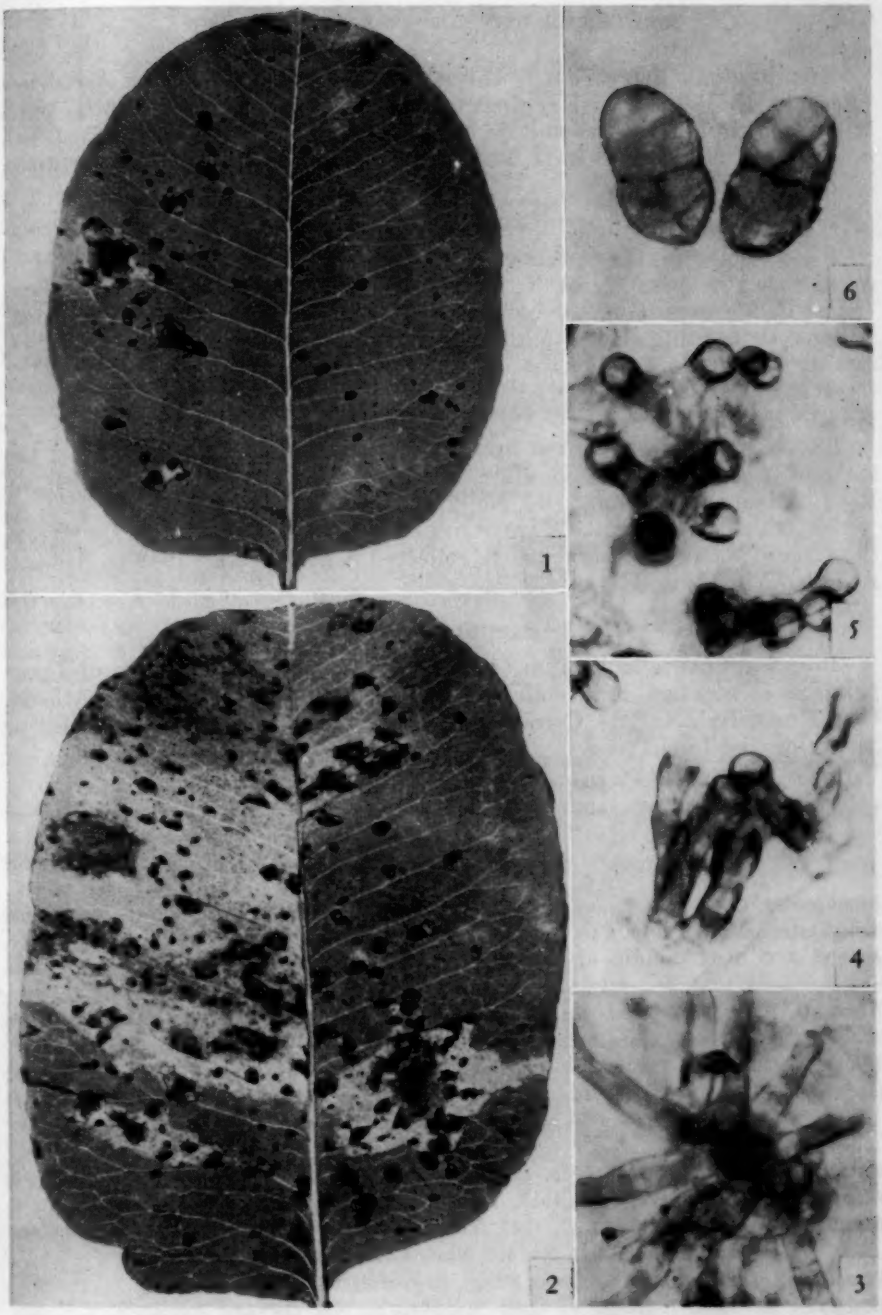
Conidia (spore body) 18–57 × 11–21 μ. Mean of spore body of ten conidia 39.1 × 15.4 μ. The beak sometimes reaches a length of 36 μ. Total length of the spore, including spore body and beak, 30–79 μ. This is the first time that *Alternaria* has ever been recorded on the present host.

STEMPHYLIUM WALLR.

96. STEMPHYLIUM BOTRYOSUM WALLR. in Fl. Crypt. 2: 300, 1833. (Syn. *Macrosporium sarcinula* Berk. and *M. parasiticum* Thüm.) on *Pistacia vera* L. collected September 28, 1940 at Botaniko, Athens. Crit. Fung. Hel. No. 161. The fungus produces leaf spots. This appears to be the first time that it has been found associated with such spots on the present host. The leaf spots are brown and more or less rounded with sharply defined margins, which usually end at the veins (figs. 1 and 2). Their diameter varies up to 15 mm. The affected areas are scattered on the surface of the blade and frequently coalesce. On them *Alternaria tenuissima* and *Cladosporium herbarum* have been found as secondary invaders.

The conidiophores (fig. 3) are erect, fasciculate, in groups ranging from 3 to 11, dark colored and often verrucose, septate, swollen at the apex to a diameter of 7–8.5 μ. The apical swelling is darker below than in the upper half and is thickened by an inner wall (fig. 5). It is also darker than the rest of the conidiophore, the darkened portion often is verrucose. Sometimes two swellings occur marking the points of sporulation (fig. 4).

The conidia are dark, muriform, verrucose, roughly oval or subangular, slightly constricted at the medium transverse septum and to a lesser degree at the other cross walls, with a prominent basal scar (fig. 6). They are produced on both sides of the leaf spot. Their size is 25.5–48 × 12–20 μ. Mean of 10 conidia, 31.8–17.6 μ.



FIGS. 1 and 2. Leaflets of *Pistacia vera*, natural size, showing spots produced by *Stemphylium botryosum*. FIG. 3. Top view of a group of conidiophores arising from a stoma. FIG. 4. Conidiophores, side view, showing terminal and subterminal swellings with a darker zone at their lower half. FIG. 5. Top and oblique view of conidiophores showing terminal swellings, similarly with a darker zone at their lower half. FIG. 6. Two muriform and verrucose conidia. All Photomicrographs × 710.

Stemphylium botryosum is the conidial stage of *Pleospora herbarum* (Pers. ex Fr.) Rabh. in Kryptogamen Flora, Vol. I, Abt. 2, p. 504, 1887. It is found in all climates and on all sorts of substrates. Neergaard (1945) mentions 16 hosts which have been experimentally shown to be parasitized by it.

CERCOSPORA FRIES

97. CERCOSPORA PETROSELINI (SACC.) SACC. (Syn. *C. apii* var. *petroselini* Sacc.) in Ann. Mycol. X, p. 321, 1912 on *Petroselinum crispum* Nym. (Syn. *P. sativum* Hoffm.) collected September 6, 1940 at Amarousion, Athens. Crit. Fung. Hel. No. 256. Conidia mostly 1-septate, terete fusoid, straight to curved, 21–37 × 6 μ.

FUSARIUM LINK

98. FUSARIUM OXYSPORUM SCHLECHT. EM. SNYDER & HANSEN from the stem of *Lycopersicon esculentum* Mill. collected September 15, 1949 at Rouf, Athens. Crit. Fung. Hel. No. 271.

99. FUSARIUM SOLANI (MART.) APP. & WR. EM. SNYDER & HANSEN from the stem of *Solanum melongena* L. collected September 11, 1949 at Kifissia, Athens. Crit. Fung. Hel. No. 269.

PAPULARIA FRIES

100. PAPULARIA ARUNDINIS (CORDA) FR.* on the base of stem of *Lycopersicon esculentum* Mill. collected September 15, 1949 at Rouf, Athens. Crit. Fung. Hel. No. 253. Conidia dark brown, lenticular, about 3–4 × 6–9 μ, occurring also in chains.

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 80, No. 4, pp. 342–348 JULY, 1953

FIFTEEN NEW ALGAE[1]

HERMAN SILVA

Of the fifteen new algae described here, eleven species and three varieties are from the writer's Tennessee Valley Studies of 1949–1951, while the remaining species is from his recent study of the Ulotricaceae. The writer is indebted to Dr. Hannah Croasdale of Dartmouth College for the Latin diagnoses.

Furcilia rotunda Silva sp. nov. (fig. 2). Cellulae lateraliter valde compressae, a latere lato visae fere circulares, duobis lobis parvis acute definitis in extremitate posteriore praeditae, a latere angusto visae obpyriformes, ab extremitate visae compresso-ovatae; pigmentatio pallida; duo flagella longitudine aequa, 1 1.4 plo longiora quam cellula; cellula 8 μ long., 8 μ lat., 4 μ crass.

Cells markedly laterally compressed, broad side view almost circular, with two small, sharply defined lobes at posterior end, narrow side view obpyriform, end view compressed oval; pigmentation light; two flagella of equal length, one and one quarter times length of body. Length equal to width, 8 μ; thickness 4 μ.

TYPE: *Furcilia rotunda.* Knox County, Tennessee in classroom material for Univ. Tenn. botany department, 11 Aug. 1949, #1706.

Oocystis brevispina Silva sp. nov. (fig. 3). Cellulae late ovate, 1–4 chloroplastos et pyrenoideum unicum omni in chloroplasto habentes; superficies membranae spinis brevibus, c. 2 μ long. aeque ornata; cellulae-filiae intra membrana cellulae-matris aliquamdiu retentae; propagatio per autosporas. Cellula 16–20 μ long., 10–20 μ diam. Colonia intra membranam obsoletam cellulae-matris retenta 40 μ diam.

Cells broadly oval; 1–4 chloroplasts, with single pyrenoid in each chloroplast; surface of the cell evenly decorated with short spines about 2 μ long, daughter cells retained within mother cell walls for some time; reproduction by autospores. Length 16–20 μ; width 10–20 μ. Colony retained within old mother cell wall, 40 μ in diameter.

CO-TYPES: *Oocystis brevispina.* Knox County, Tennessee in stagnant pond by Riverside Drive east of Knoxville Waterworks, 25 July 1949, #1585—gold fish pond at Knoxville Waterworks, 25 July 1949, #1575.

Oedogonium Kurzii var. **ovatum** Silva sp. nov. (fig. 5). Planta monoecia; oogonium singulare, ovatum aut subellipticum, poro superiore; oospora plerumque ovata, membrana levi; antheridia hypogena aut dispersa.

	Longitudo	*Latitudo*
Cellulae vegetativae	90–250 μ	44–53 μ
Oogonium	111–130 μ	70–95 μ
Oospora	80–100 μ	67–90 μ
Antheridium	6– 16 μ	44–25 μ

[1] Contribution from the Botanical Laboratory, The University of Tennessee, N. Ser. No. *143.*

Monoecious; oogonium single, ovoid or subelliptic, pore superior; oospore usually ovoid, wall smooth; antheridia hypogenous or scattered. Differs from the typical primarily in the ovoid shape of the oospores.

TYPE: *Oedogonium Kurzii* var. *ovatum*. Montgomery County, Tennessee in large marsh by Norfleet & Sons grocery by hwy. U. S. 79 west of Clarksville, 14 July 1949, #1376.

Oedogonium sphaerico-inconspicuum Silva sp. nov. (fig. 6). Planta dioecia; oogonia 1–2, spherica in parte inflata, operculata, divisione media, mediocri latitudine; oospora spherica, partem inflatam oogonia implens, membrana levi.

	Longitudo	*Latitudo*
Cellulae vegetativae	15–35 μ	3– 5 μ
Oogonium	14–16 μ	14–16 μ
Oospora	13–15 μ	13–15 μ

Dioecious; oogonia 1–2, spherical for inflated portion, operculate, division median, of medium width; oospore spherical, filling inflated part of oogonium, wall smooth.

TYPE: *Oedogonium sphaerico-inconspicuum*. Obion—Lake Counties, Tennessee at Reelfoot Lake around Nix Towhead, 15 June 1950, #2263.

Quite possibly additional observations might necessitate the reassignment of this plant to *Oedogonium inconspicuum* Hirn, but for the present it is separated because of the consistently spherical oospores and wider division of the operculum.

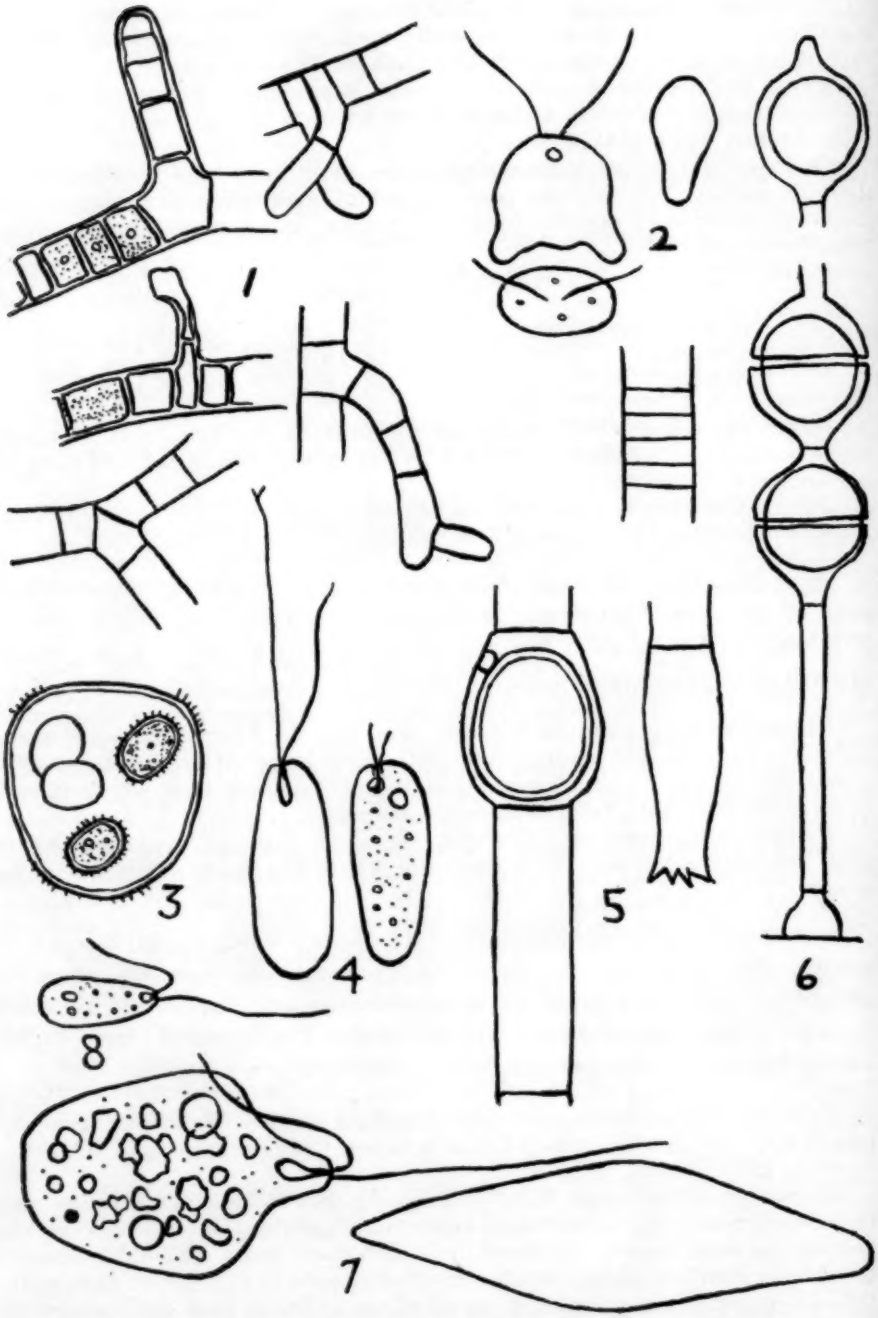
Rhizoclonium giganteum Silva sp. nov. (fig. 9). Filamenta non ramosa, cellulis cylindricis; chloroplasti reticulati, irregulares aut pyrenoideis multis sparsisque rupti; proprii generi; cellulae cylindricae, 1½–3 plo longiores quam latae, 240–280 μ lat. Planta exsiccata crispa.

Filaments unbranched; cells cylindrical, 1.5–3 diameters long; chloroplast reticulate or broken as is characteristic of the genus; cells 240–280 μ broad.

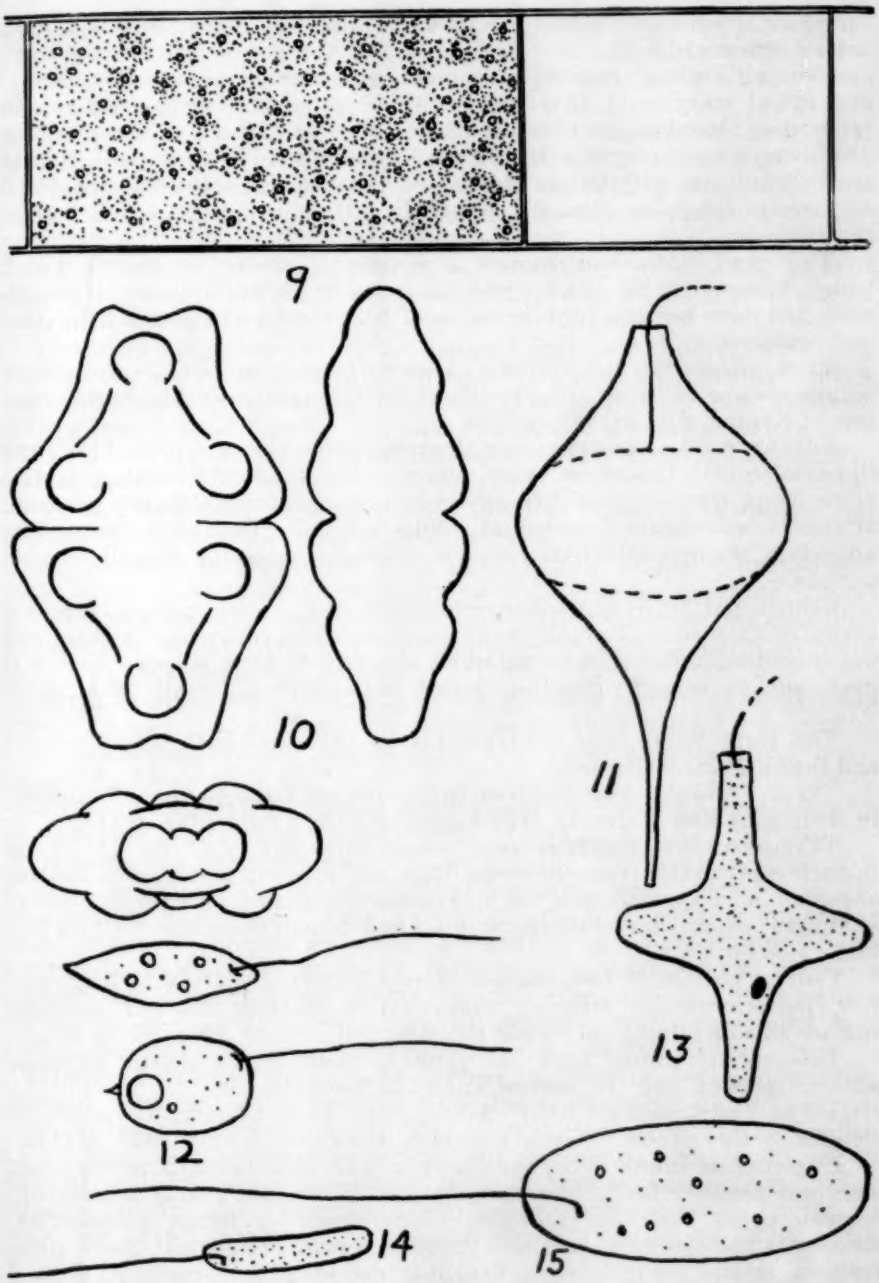
In dried condition the filaments tend to have a kinky appearance which is not noticeable in fresh specimens. The specimens differ from *Rhizoclonium hieroglyphicum* (Ag.) Kütz. by their enormous size, the largest recorded for a uniseriate filament in strictly fresh water. The largest *R. hieroglyphicum* the writer has ever encountered was about 80 μ in diameter.

TYPE: *Rhizoclonium giganteum*. Cheatham County, Tennessee in rocky limestone creak near Turnbull Creek between Craggie Hope and Kingston Springs, 21 July 1950, #2308.

Euastrum tribulbosum Silva sp. nov. (fig. 10). Semicellula a fronte visa truncata-pyremidalis, apice satis angusto, marginibus lateralibus apicalibusque concavis, sinibus equatorialibus linearibus, satis profundis, angulis basalibus rotundatis; tres protuberationes bulbosae in superficie: duae equatoriales atque tertia ad apicem; semicellula a latere visa bulbosa, protuberationibus visibilibus et ad apicem truncatum attenuatis; a polo visa



FIGS. 1–8. FIG. 1. *Ulothrix Dotyi* × 1000. FIG. 2. *Furcilia rotunda* × 1000. FIG. 3. *Oocystis brevispina* × 500. FIG. 4. *Heteronema bifurcata* × 1000. FIG. 5. *Oedogonium Kurzii* var. *ovatum* × 500. FIG. 6. *Oedogonium sphaerico-inconspicuum* × 1000. FIG. 7. *Heteronema nebuloglabra* × 1000. FIG. 8. *Heteronema longiovata* × 1000.



FIGS. 9–15. FIG. 9. *Rhizoclonium giganteum* × 125. FIG. 10. *Euastrum tribulbosum* × 1000. FIG. 11. *Trachelomonas ensifera* var. *spikata* × 1000. FIG. 12. *Euglenopsis minor* × 1000. FIG. 13. *Trachelomonas ensifera* var. *depressa* × 1000. FIG. 14. *Scytomonas stene* × 1000. FIG. 15. *Scytomonas ovatum* × 1000.

complexa, plerumque autem elliptica. Cellula 60 μ long., 40 μ lat., 20 μ crass.; isthmus 10 μ lat.

Semicell outline truncate pyramidal with fairly narrow apex, lateral and apical margins of face view concave; equatorial sinuses linear and fairly deep; basal angles of semicells rounded; face raised in three bulbous protuberances, two equatorial and the third toward the apex; side view of semicell bulbous, with bulges visible and tapering to atruncate apex; end view complicated, but generally elliptic in outline. Length 60 μ; width 40 μ; thickness 20 μ.

This newly described species is nearest *Euastrum crassicolle* Lund. which, however, is far smaller and has poles which are broader in proportion. The three bulbous protuberances of both species are identical in form and prominence.

TYPE: *Euastrum tribulbosum*. Gibson-Obion Counties, Tennessee, in bottom coating in upper pond fertilized for fish raising on Abe Shatz' farm east of Kenton, 8 July 1949, #1238.

TRACHELOMONAS ENSIFERA var. **depressa** Silva var. nov. (fig. 13). Testa in parte centrali transverse ovata, margine aequo, ad extremitatem acutam posteriorem, obtusam, non cuspidiformem primum abrupte, deinde gradatim attenuata; extremitas anterior ad collum longum cylindricum formandum admodum abrupte attenuata; superficies levis; longitudo flagelli non observata.

Central portion of test transversely oval, with an even margin, tapering abruptly, then more gradually to an acute posterior end, which is blunt and not spike-like; anterior tapering quite abruptly to form a long cylindrical neck; surface smooth; flagellum length not observed. Length 50 μ; width 35 μ.

This form differs from the typical in its depressed oval central portion and the blunt posterior end.

TYPE: *Trachelomonas ensifera* var. *depressa*. Lake County, Tennessee, in sloughs by hwy. Tenn. 78 near Kentucky line, 5 July 1949, #1192.

TRACHELOMONAS ENSIFERA var. **spikata** Silva var. nov. (fig. 11). Testa in parte centrali transverse depresso-ovata, ad cuspidem posteriorem longam, angustam abrupte attenuata, ad aperturam flagellarem anteriorem concave attenuata; superficies levis; longitudino flagelli non observata. Cellula 80 μ long., 40 μ lat.

Central portion of tests depressed oval, tapering sharply to long, narrow, posterior spike, tapering concavely to anterior flagellar opening; surface smooth; flagellum length not observed. Length 80 μ; width 40 μ.

This variety differs from the typical chiefly in its shorter tapering anterior portion and the narrow spike-like posterior end.

TYPE: *Trachelomonas ensifera* v. *spikata*. Lake County, Tennessee, in sloughs by hwy. Tenn. 78 near Kentucky state line, 5 July 1949, #1192.

Euglenopsis minor Silva sp. nov. (fig. 12). Cellulae satis metabolicae; ambitu normaliter fusiformae, subsphericae, autem, aut ovatae in metabole, acumen breve posterius interdum visum etiam in forma subspherica; striationes spirales periplasti non visibiles, forsan praesentes; grana paramylacea magna rotunda visa; flagellum excentricaliter positum, circa 2 plo longius quam corpus. Cellula 12–15 μ long., 7–12 μ lat.

Cells fairly metabolic; shape normally fusiform, but becoming subspherical or oval in metaboly, short posterior point may be evident even in the subspherical shape; spiral striation of periplast not visible, perhaps

present; large round paramylum bodies present; excentrically placed flagellum, about two times length of body. Length 12–15 μ; width 7–12 μ.

This species is somewhat more metabolic, and much smaller than *Euglenopsis vorax* Klebs.

TYPE: *Euglenopsis minor*. Overton County, Tennessee, in margins of artificial lake in Standing Stone State Park, 15 July 1949, #1418.

Heteronema bifurcata Silva sp. nov. (fig. 4). Planta aliquantum metabolica, ambitu elongato-ovata aut cylindrica, natans interdum subcurvata; periplastus ut videtur levis; flagellum crassius prorsus extensum 1 2/3 plo longius quam corpus et in extremitate perspicue difurcatum, insertio flagelli in gulam insertioni *Peranemae trichophorae* (Ehr.) Stein. similis. Cellula 28 μ long., 10 μ lat.

Considerably metabolic; shape elongate-oval or cylindric, sometimes slightly curved when swimming; periplast apparently smooth; heavier flagellum extending forward 1 2/3 lengths of body and definitely bifurcate at tip, insertion of flagella in gullet, similar to *Peranema trichophora* (Ehr.) Stein.; secondary, thinner, flagellum slightly shorter. Length 28 μ; width 10 μ.

TYPE: *Heteronema bifurcata*. Knox County, Tennessee, in quiet water of pond at Carter's Mill, 2 Aug. 1949, #1615.

Heteronema longiovata Silva sp. nov. (fig. 8). Planta elongato-ovata, parte latissima posteriore; periplastus ut videtur levis; flagellum longius crassiusque prorsus extensum, circa 1½ plo longius quam corpus, flagellum secondarium, tenuius tractum, longitudine circa dimidia parte corporis. Cellula 12–16 μ long., 6 μ lat.

Elongate-ovoid with broadest portion posterior; periplast apparently smooth; longer, heavier flagellum extending forward about 1.5 lengths of body; secondary, thinner flagellum trailing, about half length of body. Length 12–16 μ; width 6 μ.

TYPE: *Heteronema longiovata*. Knox County, Tennessee, in goldfish pool at Knoxville Waterworks, 25 July 1949, #1581.

Heteronema nebuloglabra Silva sp. nov. (fig. 7). Planta maxime metabolica, ambitu fusiformis ad urceolatam, aut ovata, parte anteriore latissima, ad basem colli hyalini, gradatim attenuati, abrupte attenuata; parte posteriore truncata aut obtuse acuminata; paramyli granula multa, irregularia, magnitudine variantia, periplastus ut videtur levis; flagellum crassius tam longum quam corpus, prorsus extensum, flagellum tenuius brevius quam corpus; nucleus magnus, anterior, lateralis; minime una vacuola pulsans posterior. Cellula 40–70 μ long., 20–30 μ lat.

Highly metabolic; shape varying from fusiform to demi-john shaped, or ovoid, broadest portion anterior, truncated or obtusely pointed posterior, anterior tapered abruptly to the base of the gradually tapering hyaline neck portion; numerous irregularly shaped paramylum granules of various sizes present; periplast apparently smooth; heavier flagellum extending straight forward about length of body; nucleus large, anterior, lateral; at least one posterior contractile vacuole present. Length 40–70 μ; width 20–30 μ.

The resemblance of this species to *Heteronema nebulosa* (Duj.) Lemm. is considerable, the only convincing difference being the distinct spiral striation of *H. nebulosa*, while *H. nebuloglabra* is smooth. Some of the cells observed were quite green, completely upsetting the writer's ideas of the

entire group, but subsequent observations showed that individuals may be colorless as well, so the color possibly was the result of ingested green matter.

TYPE: *Heteronema nebuloglabra.* Tennessee, in common culture from collections made during summer of 1949. 7 March 1950, #2223.

Scytomonas ovatum Silva sp. nov. (fig. 15). Cellulae sine colore, non metabolicae; a latere lato visae ovatae, extremitatibus rotundatis, subattenuatis; striae longitudinales et costae nullae; paramyli granula parva; vacuola pulsans non observata; flagellum paulo ad 1½ plo longius quam corpus. Cellula 50 μ long., 20 μ lat.

Cells colorless and ametabolic; broad side view oval-shaped with somewhat tapered, rounded ends; no longitudinal ridges or striae apparent; small paramylum granules present; contractile vacuole not observed; flagellum of slightly more than body length to 1.5 times length of body. Length 50 μ; width 20 μ.

The appearance is somewhat similar to *Scytomonas stene* Silva, which is considerably smaller. The flagellum is inserted as in *Peranema trichophora* (Ehr.) Stein, i.e., through a gullet and curved to one side.

TYPE: *Scytomonas ovatum.* Tennessee, in common culture of material collected in summer of 1949. 7 March 1950, #2224.

Scytomonas stene Silva sp. nov. (fig. 14). Cellulae sine colore et non metabolicae, a sectione transversa visae admodum rotundae aut ovatae; a latere visae perlonge ovatae, extremitatibus rotundatis, costae longitudinales et striae non visae; granula minuta paramyli; vacuolae pulsantes non observatae; flagellum aeque longum ac corpus vel longius. Cellula 24–30 μ long., 4–5 μ lat.

Cells colorless and ametabolic; essentially round or oval in cross section. Shape very long oval with rounded ends, no longitudinal ridges or striae apparent; minute paramylum granules present; contractile vacuole not observed; flagellum length of body or longer. Length 24–30 μ; width 4–5 μ.

TYPE: *Scytomonas stene.* Montgomery County, Tennessee, in woods pond east of Shady Grove, 3 Sept. 1949, #1910.

Ulothrix Dotyi Silva sp. nov. (fig. 1). Planta marina; filamenta penicillos olivaceo-virides formantia; cellulae cylindricae, 6–7 μ diametro mediocri; ½–1½ plo longiores; membrana crassitudine mediocri; chromatophorus speciminum exsiccatorum flavo viridis, lamelliformis, in uno latere fortasse plicatus, pyrenoideo indistincto; rami multicellulares proprii, quam filamenta principilia saepe minores, et in formas rhizoideas expandentes; propagatio ignota.

Plants marine; filaments forming olive-green tufts; cells cylindrical, median size 6–7 μ in diameter; length about ½–1½ times width; cell wall of medium thickness; chromatophore in dried specimens a yellowish green plate possibly folded at one side, pyrenoid indistinct; multicellular branches characteristic, often smaller than main filament and spreading into rhizoid shapes; reproduction unknown.

TYPE: *Ulothrix Dotyi.* Winchester Bay, Douglas County, Oregon. On wood work of Charlie Mack's Dock. Maxwell S. Doty 4716. July 3, 1942, Det. M. S. Doty as *Hormidium rivulare* Kuetz.

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BULLETIN OF THE TORREY BOTANICAL CLUB

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TORREYA

RELATIONSHIP IN THE MAGNOLIACEAE AS DETERMINED BY THE PRECIPITIN REACTION[1]

M. A. JOHNSON

The genus *Illicium* and several other genera not under consideration here have long been classified in the Magnoliaceae (DeCandolle 1824–1873) and are still retained there in certain taxonomic manuals (Rehder 1940). Hutchinson (1921, 1926) delimited the Magnoliaceae so that it contained six genera, viz. *Magnolia, Michelia, Talauma, Manglietia, Aromadendron,* and *Liriodendron.* To these Dandy (1927) added the four Asiatic genera, *Alcimandra, Kmeria, Pachylarnax,* and *Elmerrilia. Liriodendron* was placed in the tribe Liriodendreae and the remaining nine genera in a second tribe, Magnoliae, which he considered to be "an extremely natural group." McLaughlin (1933), on the basis of wood anatomy, came to the conclusion that *Illicium* is not a member of the Magnoliaceae and in fact does not even belong in the Winteraceae as proposed by Hutchinson (1921). Instead he would make it the type of a monotypic family to be placed in the Hamamelidales.

It would seem that possible relationship among these plants might be profitably approached from another type of evidence. Biochemical data on protein similarity, as revealed by the precipitin reaction (Kraus 1897), have been extremely useful in similar studies in both animals (Nuttall 1901, Boyden 1942) and plants (Chester 1937). The results reported in this paper are from a preliminary study of the seed proteins of *Illicium anisatum, I. floridanum, Magnolia viriginiana, M. tripetala, M. kobus, M. obovata, M. portoricensis, Michelia champaca, Talauma candolleri* and *Liriodendron tulipifera.*

Proteins, presumably globulins, were isolated in partially purified form and injected into the rabbit as the experimental animal. Antisera containing antibodies against the injected proteins were presently obtained from the experimental animals. When such an antiserum was reacted with the injected protein an abundant precipitate was produced; this is said to be the homologous reaction. However, when protein from a related species was reacted with this antiserum a smaller amount of precipitate resulted; this is known as the heterologous reaction.

The procedure followed in making the precipitin test has been to react a given antiserum with the antigen (protein) in a long series of doubling dilutions which begins with an excess of antigen and ends with an excess of antiserum. The turbidity (precipitate) produced through the entire range of reaction between antigen and antiserum was measured by a specially designed turbidimeter (Libby 1938) and expressed in turbidity units representing precipitin activity from antigen excess to antiserum excess. Further details as to methods and techniques will be published elsewhere.

Within the genus, *Magnolia,* it was found that antisera against *M. virginiana* reacted strongly with protein from *M. kobus.* Likewise antisera against *M. tripetala* gave a strong reaction with protein from *M. obovata.* In no instance was the heterologous test as strong as the homologous. The close similarity between the proteins, as revealed by the precipitin test, in these American and Japanese species is in accord with observations made by plant geographers on the similarity between many Eastern North American and Japanese species. In tests involving *M. tripetala, M. obovata* and *M. portoricensis* it was found that the latter was quantitatively more distinct from *M. tripetala* and *M. obovata* than *M. tripetala* is from *M. obovata.* If *M. portoricensis* is representative of the West Indian magnolias this evidence would support the growing tendency to consider the West Indian species as a distinct group within the genus.

[1] Condensed from the address of the Retiring President of the Torrey Botanical Club, entitled: A rabbit's eye view of relationship in the Magnoliaceae.

Strong reactions were obtained between *Magnolia*, *Michelia*, and *Talauma* which may be interpreted as supporting Dandy (1927) in his contention that the Magnoliae "is an extremely natural group." *Liriodendron*, on the other hand, gave a relatively much weaker reaction with *Magnolia* which would be in accord with isolating it in the monotypic tribe, *Liriodendroneae*.

Good reactions were obtained between the Asiatic *Illicium anisatum* and the American *I. floridanum*. To date both *I. anisatum* and *I. floridanum* have given negative results when tested against *Magnolia kobus* and *M. tripetala*. This, together with morphological and anatomical evidence supports the wisdom of transferring *Illicium* from the Magnoliaceae. The next step will be to determine whether positive precipitin tests can be secured between *Illicium* and some member of the Hamamelidales. A more extended study of protein similarity is being undertaken and will be extended further in the Magnoliales as a more complete collection of seed can be assembled.

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Note on the Flora of South-Central Texas

Bupleurum rotundifolium L. Thoroughwax. A single vigorous specimen of this species occurred as a volunteer in an abandoned flower bed in College Station, Texas. In the growing season of 1952 the flower bed had been used for morning glory vines and had been weeded and cultivated. It was impossible to permit the plant to grow to maturity due to damage inflicted to the plant by dogs. According to Mathias and Constance (1951) the species has been "sporadically introduced in the southern Blackland Prairies (of Texas)," citing one collection from Travis County and one collection from Washington County. Although slow starting, it is possible that this plant will become established as a weed in south-central Texas in the same way, according to Gleason (1952) that it has in other parts of the United States. Further observations will be of interest. The plant is preserved as a specimen in the Herbarium of the Department of Biology, A. and M. College of Texas, Sperry, 3247, collected March 25, 1953.—JOHN J. SPERRY, Department of Biology, A. and M. College of Texas, College Station, Texas.

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Book Reviews

Developmental Plant Anatomy. A Workbook for Use in a General Course. By Richard A. Popham. xxiv + 180 pp. + 73 full page plates. Loose leaf, paper cover. Long's College Book Company, Columbus, Ohio. 1952. $4.50.

In the Preface the author presents this workbook as a framework of questions, concepts, references, diagrams and tables, photomicrographs and drawings for observation-discussion studies on the root, hypocotyl, stem, leaf and their tissues from the standpoint of origin, differentiation, growth, and maturation. Illustrations are provided so that the student will have more time for observation and will become acquainted with more variations in plant structure. It is suggested that labelling of drawings might be done outside of class as a review and as an analysis of the discussion.

Each section usually begins with some general questions and terms. Following this, the section is outlined very nicely to answer the questions raised, with each topic usually having one or more covering references, a series of related questions, and an extensive list of suggested materials. The included photomicrographs are superb and the materials figured are readily available so that corresponding slides could be provided. However, since the emphasis is on cell types and organization, the slides would not need to correspond to the figures.

As a matter of personal preference, this reviewer would prefer to begin with a study of cell types, which comes at the end, and to end with the present introduction, which could well serve as a summary. The loose-leaf format makes this possible. The treatment of flowering is brief and limited to the apex. Stages in fruit or seed development are lacking. Tissue and organ differentiation in embryos is covered adequately. On the stem, the studies are largely confined to patterns of development and do not include many details of stem anatomy, such as the ontogeny of xylem elements. However, the book now contains more than can be covered in one semester.

Any teacher or student of anatomy or morphology will find the general references, the topical organization and synthesis of materials with author listings, and the photomicrographs a valuable tool to have available. In using this as a text, the success of this approach requires a large selection of suitable materials and, in particular, an alert, well-prepared and well-informed instructor. Whether or not one agrees with the method of presentation or with all of the concepts, it is a new and challenging approach to a dynamic subject.—James E. Gunckel, Department of Botany, Rutgers University, New Brunswick, N. J.

Respiration in Plants. By Walter Stiles and William Leach. 172 pages. John Wiley & Sons, Inc. New York. 3rd edition, 1952. $2.25.

Advances since the publication of the 2nd edition of this Methuen monograph in 1936 required an almost complete revision of the chapter on the mechanism of respiration, which now makes up about two-fifths of the text. Parts of a condensed statement of the steps in the Krebs cycle are not in complete agreement with the authors' elaboration following the statement in question.

A great deal of information is packed into this pocket-sized monograph, parts of which can be read easily by the beginner. The discussion of the mechanism of respiration,

however, seems to be addressed to the more advanced student, although not to the specialist in the field.—HAROLD E. CLARK, Department of Plant Physiology, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

Morphogenesis in Plants. C. W. Wardlaw. xi + 176 pages, 4 plates and 42 text illustrations. Methuen & Co. Ltd. London. John Wiley and Sons. N. Y. $2.25.

No botanist can afford to be without this little pocket book (format $4 \times 6\frac{1}{2}$ inches) in which Professor Wardlaw has succinctly reviewed and brought into focus our knowledge of morphogenesis. The extensive literature, 256 citations are listed in the bibliography, is organized and presented under the following topics: embryology, shoot apex, experiments on the shoot apex, leaf formation problems, mechanical relationships, biochemistry and morphogenesis, genetical control of morphogenesis, and genic action in morphogenesis.

A work of this type should define the problems in the field under consideration and offer suggestions as to how their solution may be attempted. Judged on this basis, Professor Wardlaw has been highly successful in his treatment of morphogenesis. He recognizes that much descriptive work on the development of form is still needed and that from such data hypotheses must be formulated and subjected to experimental testing. The culture of embryos, organs, and tissues in nutrient media in which nutrients and growth substances can be controlled, surgical treatments applied to apices and leaf primordia, the influence of environment, the experimental establishment of gradients and growth centers, and changes in space relationships resulting from growth of the organism are recommended as some of the most promising working methods of experimental morphology. We are reminded that morphogenic events are seldom if ever simple; they are controlled by many factors, few of these can be isolated for direct study and they probably never act alone in the organism. Thus, the solution of morphogenic problems is envisioned as requiring an integration of morphology, anatomy, histology, physiology, biochemistry, ecology, genetics as well as the utilization of physical and mathematical laws. And finally "... the concept of development is essentially an epigenetic one, *i.e.* each succeeding phase is held to be effected by the antecedent phase, and all implications of preformation (where the process of development is regarded as the unrolling or manifestation of preformed parts) are ruled out."

Certain other features are worthy of special mention.

First of these is the role of biochemical processes in morphogenesis; while it is impossible to separate biochemical from physical factors yet "—the master factor seems likely to be biochemical in nature." Accordingly attention is given to the biochemical aspects of growth-regulating substances and their effect in organ formation, auxins and polarity, the formation of roots, leaves and vegetative buds, the induction of flowering, histogenesis, and differentiation in tissue culture.

Second, some of the more important aspects of genic control in morphogenesis are discussed *i.e.* effects resulting from change of gene position in the chromosomes, cytoplasmic inheritance, effects of gene mutations, interpretation of genic action, the time of gene action, and genic constitution and environment.

Third, an excellent account is given of the author's extensive experiments on the apical meristerms and leaves of ferns. This has been integrated with the researches of his contemporaries in corresponding regions of the seed plants.

A word should be said in behalf of the illustrations for they have been selected with discrimination and faithfully reproduced. Also the text is unusually free from typographical errors.—MARION A. JOHNSON, Department of Botany, Rutgers University.

The Tropical Rain Forest, an ecological study. By P. W. Richards. xviii + 450 pages; 15 plates, 39 tables and 43 figures. Cambridge University Press. 1952. $12.50.

"The tropical rain forests include about half of the world's forested area. Until recently man had had little effect upon them . . . they have probably persisted unchanged from the remotest times. . . . In the last hundred years . . . the rate of destruction is so rapid that unless efforts are made to preserve it the tropical rain forest may well disappear within a lifetime. . . ."

Three main regions of rain-forest vegetation are recognized—South America, Africa, Malaysia. Professor Richards has had first-hand experience in all of them. This has put him in touch with a good deal of unpublished data as well as reports from various tropical stations. His References run to some 480 titles dating from 1817 to 1949, disregarding a quotation from Christopher Columbus (1493).

The book is designed for anyone interested in the tropical rain forest, professional or layman. The result is most fortunate. There are few technical terms, all brought in so as to be easily understood yet the book does not lack in scholarly presentation. Technical data is brought in on the basis of the author responsible for it but mostly stripped down to the pertinent figures or a summary statement. The text is easy to read, interesting, and relatively free of monotony.

The rain forest is characterized by woody plants in great numbers of individuals and species though of rather monotonous, superficial resemblance to laurel. The trees may average taller, but mostly of less diameter than those of temperate latitudes. Palms and other species of divergent types may or may not be present. Herbaceous plants are proportionally fewer than in temperate forests. The uniformly favorable and non-seasonal climate does not favor the life-forms adapted to recurring periods of adversity and such forms are lacking in the biological spectrum. Epiphytes are very numerous, many of them woody. Families limited to herbs in Grays Manual have woody species in the tropics. "Violets of the size of apple trees" (page 3). Several misconceptions of the Tropical Rain Forest are corrected in the Introduction, *e.g.*, it is not impenetrable, nor is it characterized by showy flowers.

The more ancient and more generalized tropical rain forest may well be the type from which plant formations specialized for less favorable climates have been derived. But of course we have studied temperate forests more. They have become our base of reference to an extent such that the more specialized arctic and more generalized rain forest communities have been dealt with as strange or exceptional.

Part I deals with structure and physiognomy. The tropical rain forest consists of three more or less sharply defined tree layers, a layer of mixed woody and herbaceous plants, and a ground layer. The canopy may be closed by any one of the tree layers or by a combination. Younger specimens of upper layer species will usually be found in all the understories. This structure is repeated, with a different set of species in the three main regions of tropical rain forest. In general the forest is dominated by a mixture of species. Single species dominance, although sometimes covering hundreds of square miles are referred to as consociations. The Mosaic Theory of Regeneration, implying a cyclic sequence of dominants in the climatic climax is discussed. There follows a chapter of rather detailed consideration of morphological characteristics of trees and shrubs and similar consideration of ground herbs and what Richards calls "the dependent synusiae." Climbers, stranglers, epiphytes, saprophytes, and parasites are recognized.

The environment is discussed in Part II. "The northern and southern climatic boundaries of the tropical rain-forest formation-type are in most places determined by precipitation and its altitudinal boundaries chiefly by temperature." The temperature limits average 68 to 82 degrees F. Extremes may be little or considerable. Other climatic factors are treated in turn. It is pointed out that the Tropical Rain Forest has less annual variation in day length, temperature and precipitation than most other plant communities. Rhythmic activity is common but not universal. Some species may have flowers and fruits at all seasons. Some species get new leaves with great regularity, but not necessarily at the same calendar season. The periods cited range from 5½ months to 2 years and 8 months. In each case the tree was observed through three or more cycles. Other species may defoliate different branches at different seasons. Soils likewise are considered as effective ecological factors.

The third part deals with the "floristic composition of climax communities" but the word "climax" must probably mean something different in the tropics than it does in the North American or Eurasian forests. It appears that more than one soil type can develop in this tropical climate and likewise there is more than one climatic climax. We must accept a polyclimax or accept the mixed rain forest as the zonal (normal) climax and consider equally stable associations on other soils or topography as azonal. Some of the other stable types of vegetation are not even forests at all.

In discussing "primary successions" in Part IV, the primary xerosere is largely a summary of reports on Krakatau. Various hydroseres are treated and coastal succession receives extended consideration. Some diagrams are included. The great age and permanence of tropical rain forest has limited the study of priseres to the extent that the information presented is admittedly fragmentary.

The great variety and extreme diversity of plant communities that are apparently climatically stable in the tropics leads to Part V, "Tropical Rain Forest under limiting conditions," where little is done beyond showing "the bewildering complexity of the problem." If the other communities are stable, their consideration is outside the limits of this book except for conditions at the ecotone. But are they stable? Stable for how long? If they are outside the climatic limit of the tropical rain forest they are likewise beyond the scope of this book. But they occur, at least some of the other apparently stable communities, within these climatic limitations. Then we find terms such as fire, local soil conditions, and others reminiscent of papers dealing with the prairie-forest ecotone of temperate climates.

"Man and the tropical rain forest," Part VI, deals with exploitation and recovery, with secondary succession and deflected successions. The problems are perhaps more complicated than in temperate climates; they have been studied less, but they are thought to be no less important.

A postscript brings the treatise to a close. This is titled, "The future of the tropical rain forest." It sets forth the recent, terrific disturbance of this community and its implications. There is a strong plea for conservation practices to minimize the adverse effects of this disturbance. The author quotes E. J. H. Corner's statement: "I fear lest all the virgin lowland forest of the tropics may be destroyed before botany awakes." It is pointed out that only through the establishment of extensive and fully protected reserves will facilities remain available for the botanical and zoological research in the tropics that is essential to the elucidation of its ecological problems.

The book presents both sides of controversial subjects. It appears to present the pertinent, current information. It is a thoroughly good treatment of the Tropical Rain Forest.—JOHN A. SMALL, New Jersey College for Women, Rutgers, The State University of New Jersey.

NOTES

Eighth International Botanical Congress—Paris, July 1954. Proposals regarding the International Code of Botanical Nomenclature (1952) must be submitted to the Rapporteur-General, Dr. J. Lanjouw before 1 December 1953. All proposals can be published in Taxon. Botanists preparing proposals are earnestly requested to give them the form of the example published in Taxon vol. 2, no. 2., March 1953. Address: Office of the Rapporteur-General, International Bureau for Plant Taxonomy and Nomenclature, Lange Nieuwstraat 106, Utrecht, Netherlands.

BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 80, No. 4, pp. 355–364 JULY, 1953

INDEX TO AMERICAN BOTANICAL LITERATURE

COMPILED BY

LAZELLA SCHWARTEN

WITH THE COLLABORATION OF THE EDITORS OF THE TAXONOMIC INDEX

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